Principles of Engineering Drawing

Leeds

D. VAN NOSTRAND COMPANY
NEW YORK

PRINCIPLES
OF
ENGINEERING DRAWING
FOR
TECHNICAL STUDENTS

BY

CHARLES C. LEEDS, B.S.

PROFESSOR OF MECHANICAL DRAWING,
CARNEGIE INSTITUTE OF TECHNOLOGY

105 Illustrations

NEW YORK
D. VAN NOSTRAND COMPANY
25 PARK PLACE
1919

TO THE

OHIO MECHANICS INSTITUTE

THE ALMA MATER WHO HAS HELPED SO MANY CINCINNATI BOYS TO GAIN A TECHNICAL TRAINING, THIS VOLUME IS GRATEFULLY DEDICATED BY ONE OF HER SONS

PREFACE

THE subject matter of this text has been carefully prepared and arranged with a view to meeting the needs of Freshman students in Engineering Schools and Colleges. It contains, in addition, ample material for the requirements of more advanced men who are interested in Engineering Drawing.

The ability to use engineering drawings intelligently presupposes the power to make mental translations from orthographic projection drawings into perspective, and from perspective back to orthographic, as these processes are constantly taking place in the various departments of manufacturing plants engaged in engineering construction.

Under the theory that as a boy grows up he develops a natural tendency to visualize objects in perspective form, the author has made use of angular perspective as a means of introducing the subject of orthographic projection, believing that a sound grasp of the latter subject may be obtained by comparing it with a known subject.

After the fundamentals of both perspective and orthographic have been studied thoroughly, we apply this instruction immediately when taking up freehand sketching, for here the student is required to use his reasoning faculties to translate perspective sketches into freehand orthographic projection drawings.

For certain other problems given in this same chapter, the student is obliged to make his sketches from a *written description* of the objects which form the sub-

ject matter of his drawings. Both of these methods of presentation, i.e., translation and written description, are valuable aids in developing the student's power to *visualize mentally*, both perspective pictures and the various orthographic views as well. The translation method is followed later when taking up isometric projection, as the problems are shown in the form of orthographic sketches from which the student is required to lay out his drawing of each object in isometric.

The primary aim in presenting these various problems in this fashion, is to enable the student to understand drawings readily, and to give him the ability to make *mental* translations quickly when objects are presented by either method, and thus to give the student confidence in his understanding of this vital feature of engineering drawing.

We have led up to the subject of "working drawings" by giving the student a thorough grounding in the technical methods followed in the production of these drawings; consequently, from this period on, it is largely a matter of applying these methods with intelligence in order to produce the creative draftsman.

The author desires to express his appreciation for the helpful suggestions given during the preparation of this text by Professors C. W. Sproull and H. L. McKee. He also wishes to acknowledge his obligation to Mr. W. A. Emery for his valuable assistance in the preparation of the various drawings.

CONTENTS

PRINCIPLES OF ENGINEERING DRAWING FOR TECHNICAL STUDENTS

CHAPTER I

PURPOSE OF INSTRUCTION

A STUDY of drawing as applied to the various forms of engineering construction is of decided importance to all students of technology. This subject has both educational and practical value of a high order, and the beginner should approach the study of drawing with a full appreciation of this fact, if he is to profit fully from his efforts.

There are few, if any, subjects of instruction so helpful in stimulating the *reasoning faculties* as a careful study of engineering drawing, and there is no subject of equal value for training the powers of *accurate perception.* Engineering drawing is a fundamental tool constantly used in developing the growth of ideas born of the *creative imagination,* a faculty vitally essential to success in the engineering field.

The name Engineering Drawing covers the various forms of drawing used in engineering construction; of these the most important are mechanical and freehand drawing.

Technically, a mechanical drawing is a drawing made with instruments; actually, in the manufacturing and engineering world, it is an instrument

or device for conveying *exact* information from one person to another. It is a graphic illustration of some mechanism or form of construction, a commercial necessity which is preliminary to all forms of engineering construction.

An engineering drawing represents the written form of a *Language*. This language may be described as a "pictorial" one, as it is by means of a drawing showing one or more views of an object that we furnish the necessary information as to the *shape* and the *size* of this object.

To be able to clearly understand engineering drawings we must learn to read and write this language by the methods in use in commercial life. This means that we must become familiar with the principles upon which the subject is founded.

In beginning the study of drawing, the student should bear in mind the fact that *all* the fundamentals of the subject are of importance, and that an understanding of these elements may be obtained only through mental and physical effort. Where the major emphasis is laid upon physical effort, the student is apt to get the impression that the important feature is to get drawings finished, rather than *how* they are finished. Manual skill is very desirable, and for draftsmen it is a necessity, but a clear understanding, based upon reasoned study of the subject matter covered, is infinitely more to be desired; for, without this understanding, original creative work is a practical impossibility.

The most desirable combination is where the student studies his drawing problems and makes a

persistent effort to reason them out, and also performs the physical part of his labors with care, neatness, and accuracy. Each time the student seriously attempts to reason out a problem, he is strengthening and developing those faculties which are vitally essential to his success in commercial life.

Whoever plans or performs creative work, such as designing some form of engineering construction, must have developed his imagination until this creative faculty enables him to visualize or form mental images of the mechanism which he is planning, which creation he transmits to others by means of freehand sketches or mechanical drawings. As a consequence it is highly desirable for the student to attempt from the very beginning to form mental pictures of the objects used as subject matter for his drawings, and thus to work toward the development of the creative imagination.

CHAPTER II

DRAWING TOOLS AND METHODS OF HANDLING

Mechanical drawings, as the name indicates, are made mechanically; that is, with instruments, as distinguished from drawings made freehand.

When taking up the study of mechanical drawing it will be greatly to the student's advantage to obtain a drawing outfit of good quality, for with proper care many of the tools will last a life time. Another reason for taking good care of the various tools is, that it is easier to do work of an excellent quality when the tools are kept in the proper condition. In general, it will be found that the careful, accurate draftsman is one who has formed the habit of keeping all of his outfit in good working order.

Pencils. — No tool is more used in making drawings than a lead pencil, and yet many students show a tendency to grow careless in regard to keeping them properly sharpened. Pencils for drawing are made of various degrees of hardness to suit the purposes for which they are to be used. Possibly the commonest method of indicating the degree of hardness is by placing a numeral before the letter H, as 2H, 3H, 4H, etc.; the harder the pencil, the higher the number preceding the H.

For *sketching*, or *printing* notes on drawings, H or 2H pencils are very satisfactory and should be sharp-

ened, with a round point, as indicated in Fig. 1, though the point should not be made as sharp as for the drawing pencil.

The pencil used for making mechanical drawings must be of a fairly hard quality to enable one to

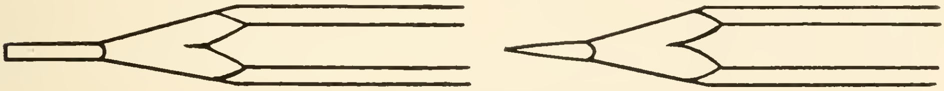


FIG. 1

maintain a good point for a reasonable length of time. For drawing on the common Manila papers, pencils of from 4H to 6H will be found entirely satisfactory, and it is recommended that one end of the *drawing* (or hard) *pencil* be sharpened as shown in Fig. 1, with a round point, and the other end as in Fig. 2, with a flat point.

Round Point. — This point is produced by first

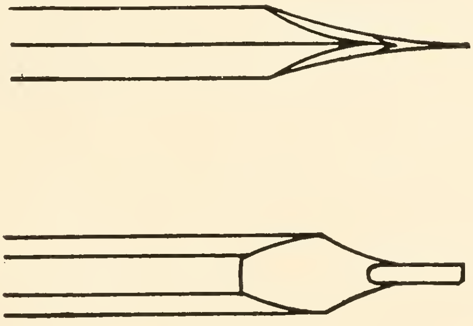


FIG. 2

cutting away the wood, as shown in the illustration, Fig. 1, and then sharpening the lead on a smooth single-cut file. About one inch from the end of the pencil, beginning on one of the six corners, cut away the wood in a clean manner so as to bare about $\frac{3}{8}$ inch of the lead; then sharpen it on the file by drawing it towards you. Turn the pencil slowly

away from you, taking a fresh hold with each stroke, so as to keep the pencil turning on its axis as it is moved along the file.

Flat Point. — The flat point is very useful when it is desired to draw very fine, accurate lines, such as center lines, construction lines, etc. In sharpening the flat point, enter the knife about one inch from the end of the pencil on one of the flat sides (not corner) and cut away the wood in the manner shown in the illustration, Fig. 2, baring about one-half inch of the lead. To sharpen the lead, slide it back and forth along the file, forming a long chisel-like point. The flat side of the lead should parallel the flat side of the pencil when the point is finished.

Paper. — The drawing paper commonly used in commercial drafting rooms is known as Manila paper. There are a great many grades of this paper manufactured, but the main points necessary to keep in mind when making a selection are: color, erasing qualities and toughness of fibre.

Commercial drafting rooms usually have three or four standard size sheets upon which all of their drawings are made; these sizes being dependent upon the product of the firm. The following sizes are suggested as they have been found very satisfactory and they may be cut from a roll with no waste: A sheet 22 inches × 30 inches, B sheet 15 inches × 22 inches, and C sheet 11 inches × 15 inches.

Drawing paper should be fastened to the board as smoothly as possible; for it is very difficult to make an accurate drawing on paper which does not lie

flat on the board. The method of mounting paper, shown in the illustration, Fig. 3, needs very little explanation, and if the student follows the directions with reasonable care, the result will be entirely satisfactory. Place the tacks in the order numbered, stretching the paper in the direction indicated by the arrows. Push the tacks well down so that the heads bind the paper closely; this will also enable the T square to slip over them easily without knocking small chips out of the edge of the blade.

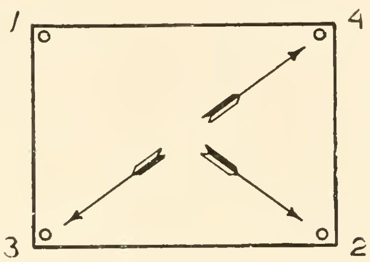


Fig. 3

Erasers. — For erasing pencil lines on Manila paper the Ruby No. 112 is excellent though the Emerald No. 111 is about as satisfactory. For cleaning pencil lines or dirt from tracings, both of these erasers are rather hard and it is preferable to use some of the softer erasers for this purpose, such as the Hardmuth soft gray cleaning rubber. To erase ink from tracing cloth an eraser of fine spun glass held in a pencil-shaped holder is one of the latest and best.

Drawing Board. — **T Square.** — **Triangles.** — The drawing board should be made of a soft wood, well-seasoned white pine or yellow poplar preferred, so that the thumb tacks may be easily pushed into or drawn from it. The left-hand edge of the board must be perfectly straight, as well as smooth and free from high spots.

A T square of well-seasoned pear wood with a thirty inch blade is inexpensive and should give

satisfactory results. The inside edge of the head and the upper edge of the blade, which are set at right angles to each other, should be perfectly straight and smoothly and accurately finished.

Triangles of some transparent material, such as celluloid, are preferable, as they are easily kept clean and are convenient to use on account of their transparency. An eight-inch 45° and an eleven-inch 30°–60° triangle will be found satisfactory for general use.

When using these tools, the head of the square is held against the left-hand edge of the board and the upper edge of the blade used as a ruling edge for *all* horizontal lines. For vertical lines, hold square as mentioned above, also hold one of the triangles as shown in the illustration, Fig. 4, and use the *left-hand* edge of the triangle for a ruling edge, always drawing the pencil *away* from the square blade when ruling a vertical line. To rule lines properly, lean the top of the pencil slightly away from the ruling edge so that the pencil point will slide along in the corner formed by the ruling edge and the surface of the paper.

Scale. — A flat 12-inch scale graduated in sixteenths on the full-size edge and in thirty-seconds on the quarter-size edge is most suitable for our purpose, as the fractions most commonly used on mechanical drawings are multiples of those numbers. A scale with white edges and dark graduation lines is highly desirable, as the use of this type is least trying on the eyes.

The student should become familiar with the use of this scale in marking off measurements, as this part of the work is of much importance in making accurate drawings.

The simplest plan to follow in laying off a given length is, to first rule a light, thin line (generally termed a construction line) in the proper position, then place the edge of the scale just against the line, now mark small pencil points on the line, *directly* opposite the graduations on the scale which indicate the desired length. Now using the square or tri-

Fig. 4

angle as a ruling edge, make the line heavy between the two points and the result is the finished line of the proper length.

Drawing to Measurements. — For practice in the use of the tools we have described, it is suggested that the student lay out the following figures with care in an effort to obtain accurate results:

Lay out an 8-inch square in the following manner:

First draw in the sides with light, thin lines, then when the proper sizes are measured off run over the lines again, making the outline of the square heavy. Also lay out a 4-inch and a 2-inch square on the same sheet of paper.

Draw a light line diagonally across each square; that is, a line from far corner to far corner, or the *longest* straight line that can be drawn inside of each square. On this diagonal line, lay off points or measurements as follows: For the 8-inch square these

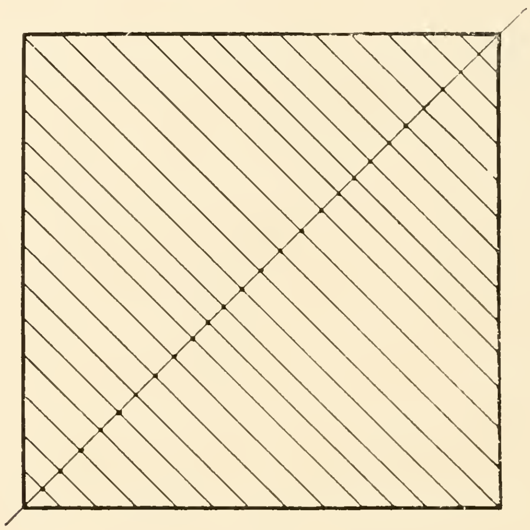


FIG. 5

points should be $\frac{1}{4}$ inch apart, starting at one corner and letting the last measurement come what it will, on the 4-inch square make the points $\frac{3}{16}$ inch apart and on the 2-inch square $\frac{1}{8}$ inch between points. Now using the *T* square and 45° triangle, with the triangle as the ruling edge, draw light lines through these points in each square, these lines to be at right angles to the diagonal line.

When drawing in these lines, care must be taken to see that they cut the center of the point and the

finished result should be three figures similar to that shown in Fig. 5.

Drawing Instruments. — The illustration, Fig. 6, shows a set of drawing instruments which includes

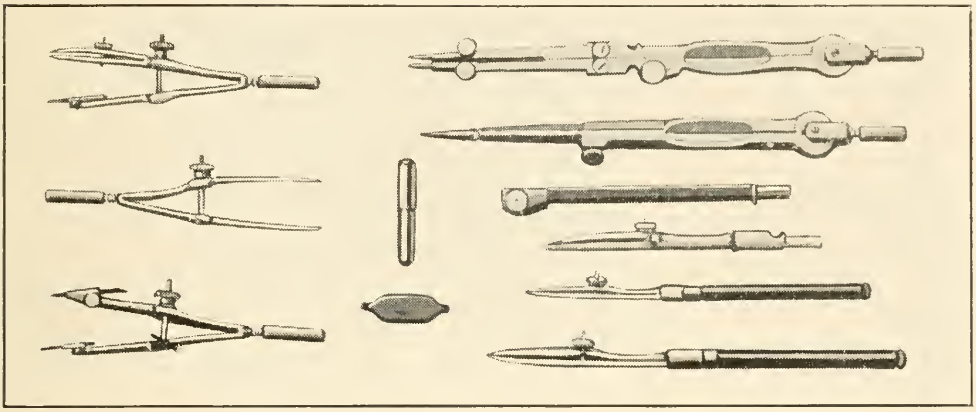


Fig. 6

all of the pieces necessary for the general run of work in a commercial drafting room. This set includes a large compass with pen and pencil points, lengthening bar, large adjustable divider, large and

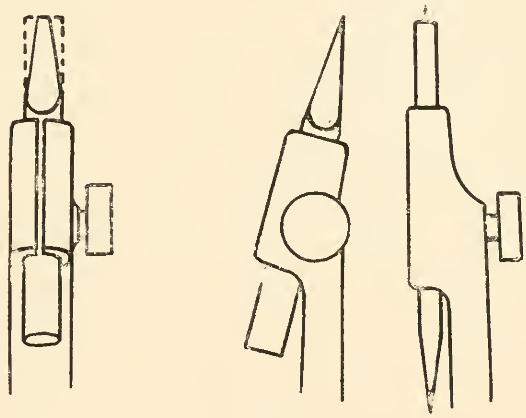


Fig. 7

small ruling pen, spring bow divider, pencil and pen, screw driver and tube for leads.

In adjusting the instruments for use, place just a touch of vaseline on each of the screws and see that

it is spread along the threads as this will keep them from wearing rapidly or stripping. When preparing the compass points, set the needle with the shoulder end out about $\frac{1}{4}$ inch from the end of the compass. Adjust the lead about even with the needle point; now with the file produce a flat point somewhat like

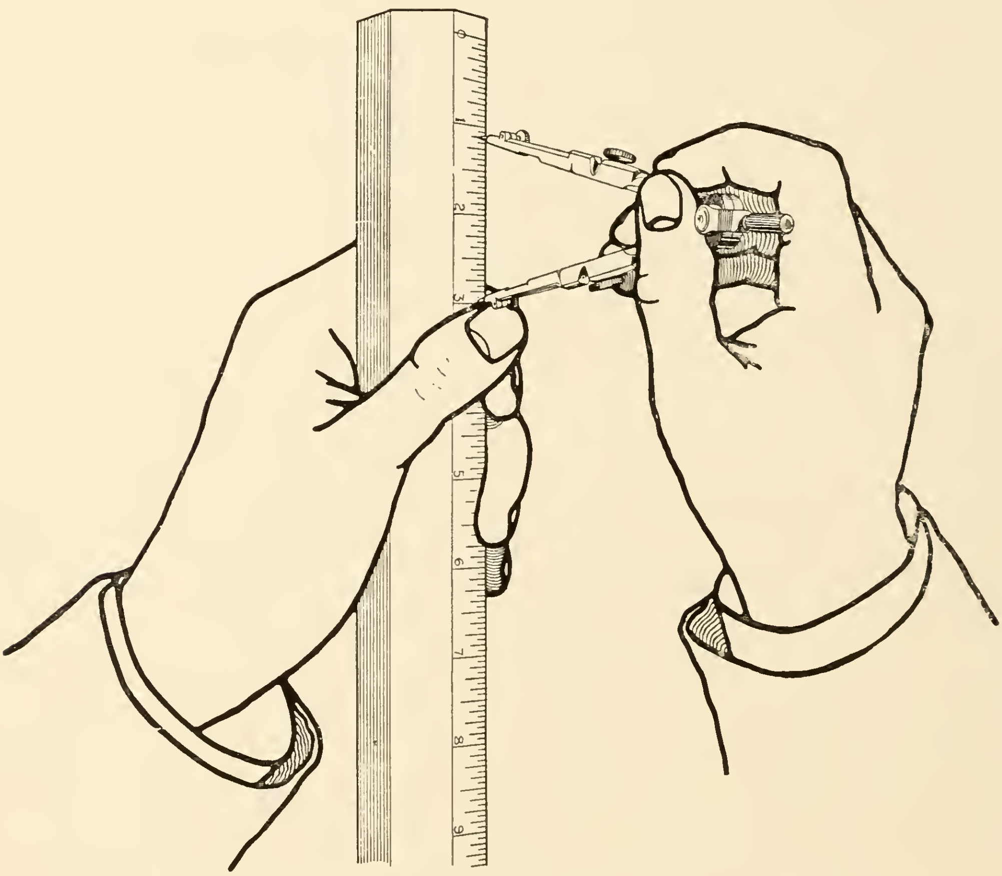


FIG. 8

a chisel point (except that it is dressed off on both sides); this flat pencil point should be set at right angles to the needle point and about even with the shoulder of the latter. After setting the lead properly, file off the corners of the flat point as shown in Fig. 7, and the result should be a fairly narrow flat pencil point, which is slightly shorter than the needle point.

Handling Compasses. — It is of importance to form the habit of handling tools in a workmanlike manner. When setting the large compass to a dimension on the scale, do this in an easy, natural manner as illustrated in Fig. 8, holding the scale with the left hand and using the thumb to help locate the needle point. The compass is held in the right hand, the adjustment of the legs being controlled by the thumb and the first three fingers.

Where the radius desired is large, bend the compass legs at the middle joint so as to keep the legs fairly perpendicular. Figure 9 illustrates this point and also shows the method of holding the compass when throwing in a circle.

When setting the spring bow compass, use the method shown in Fig. 10, as by this means the scale and compass points are both easily seen, which is an important feature; and further with this position, by rolling the adjusting nut between the thumb and second finger it is very easy to obtain the desired measurement accurately.

Finding Radius Center. — Before starting some of the problems which follow it, may be well to explain an excellent method of finding the radius center when throwing in round corners. The method suggested, for lack of a better name, we have given the title "trial method," as it is by trial that we locate the proper position for the compass needle. This method applies equally well to all angle corners, and tends to promote speed in production.

To find the radius center, place the compass in such a position that the lead point rests directly upon one of the corner lines which are to be joined,

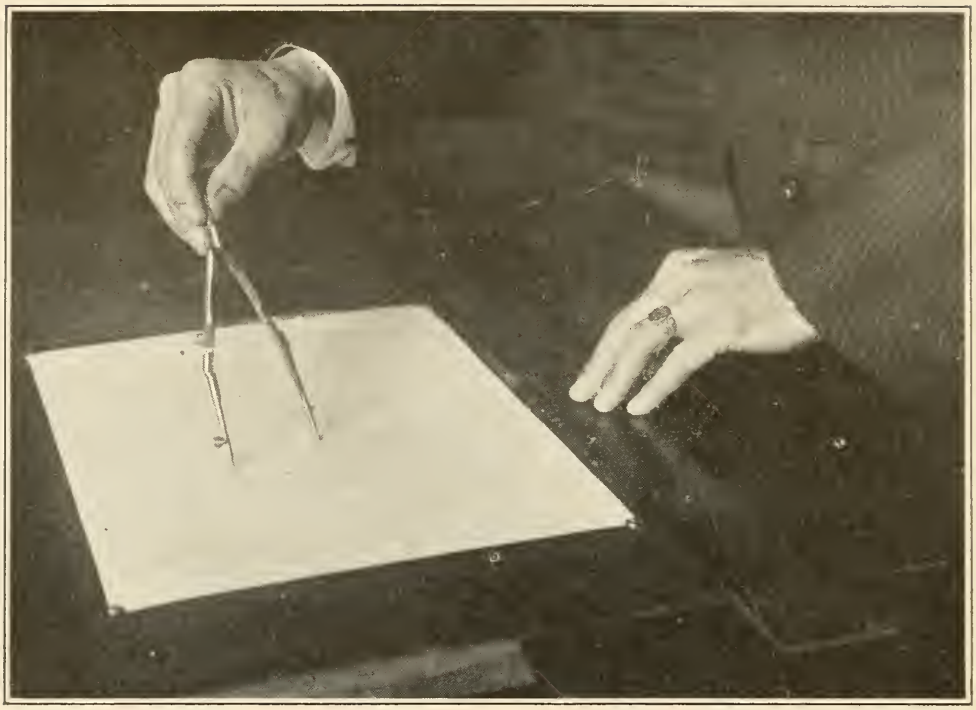


Fig. 9

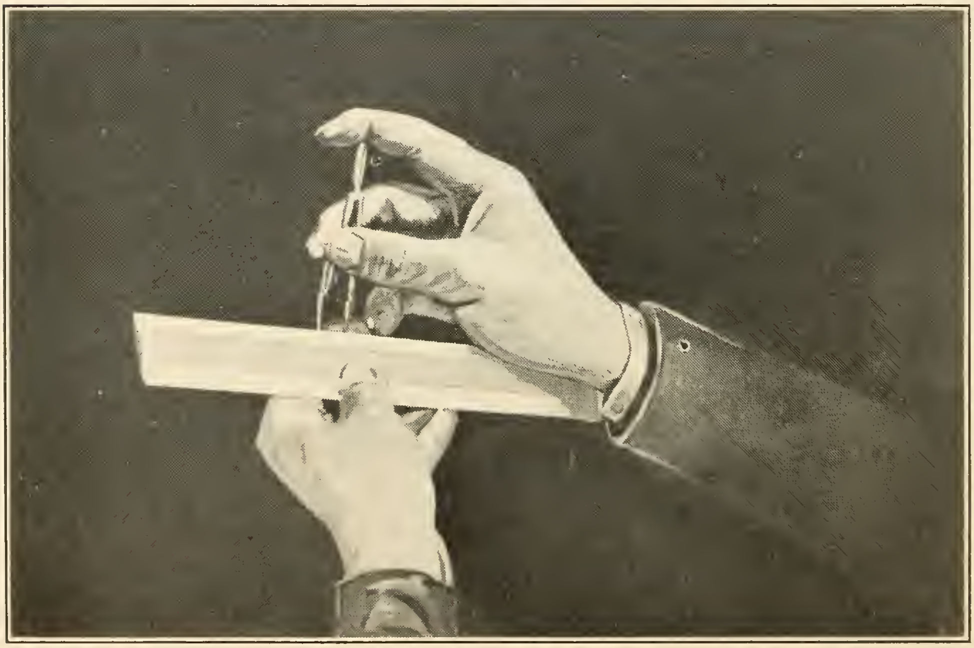


Fig. 10

then rest the needle point *lightly* on the paper in the position which the eye indicates as the center. Now balance the compass *lightly* on the needle point and swing the lead point around to the other corner line; if this point comes directly on the line, the needle position is correct and the radius may be thrown in. If this position is not quite right, swing the lead point back to the original line, balance on this and shift the needle point the amount judged to be necessary.

Practice Problems. — The following problems have

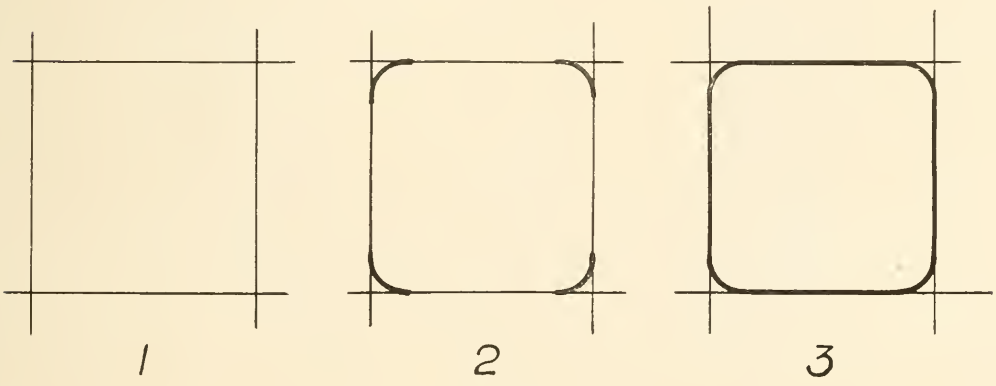


FIG. 11

been prepared for the purpose of furnishing practice in the use of the instruments. Using light, thin construction lines, lay out a 4-inch square, an equilateral triangle with 5-inch sides, and a rhombus with 5-inch sides. The smaller angle between the sides of the latter figure is to be 45°. Round the corners of each of these figures with a $\frac{1}{2}$-inch radius, using the trial method to find the radius centers. Make these round corner lines fairly heavy when throwing them in, then "line in" the rest of the figure, making the whole outline of the same thickness as illustrated for the square in Fig. 11.

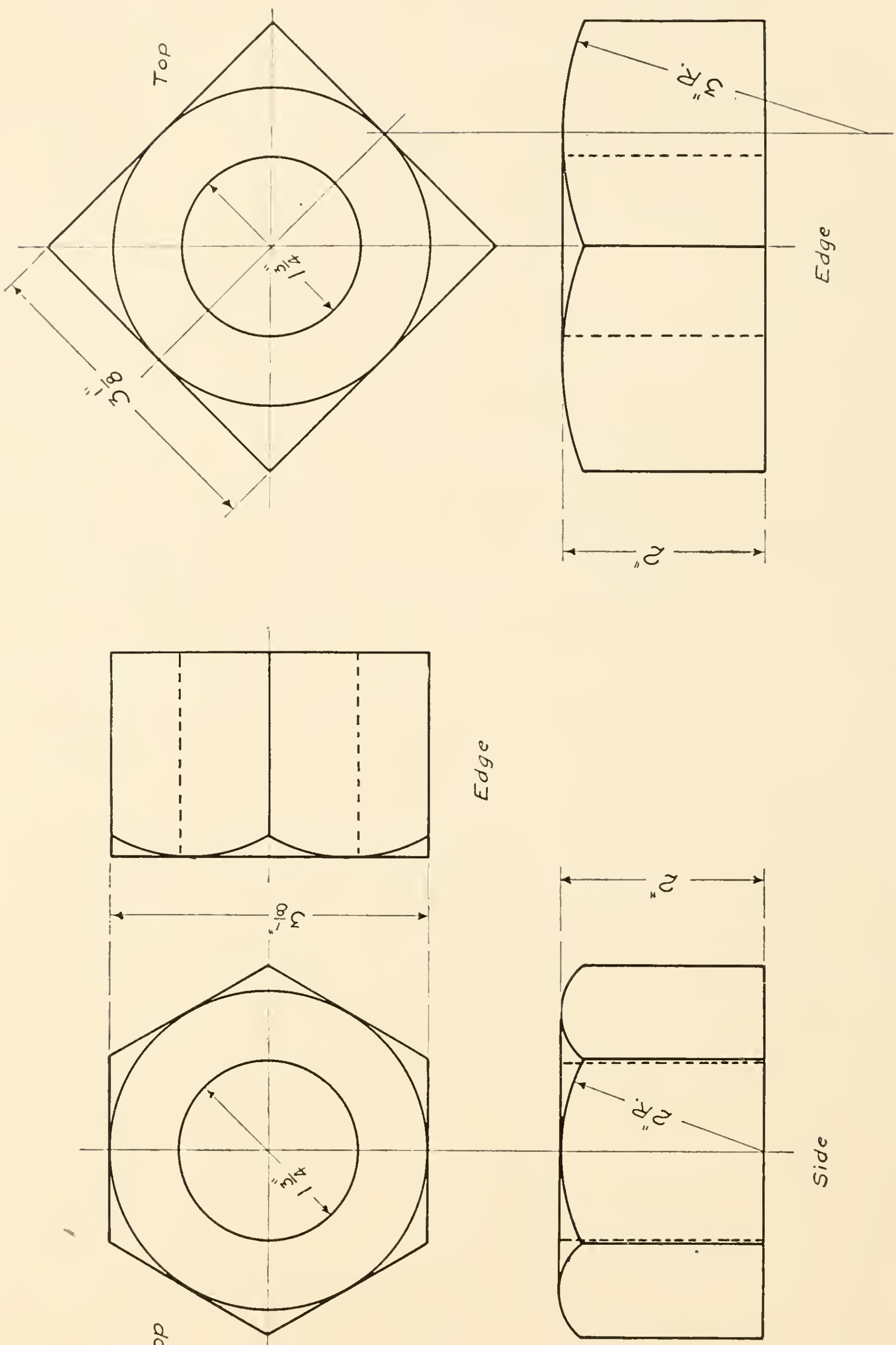


Fig. 12

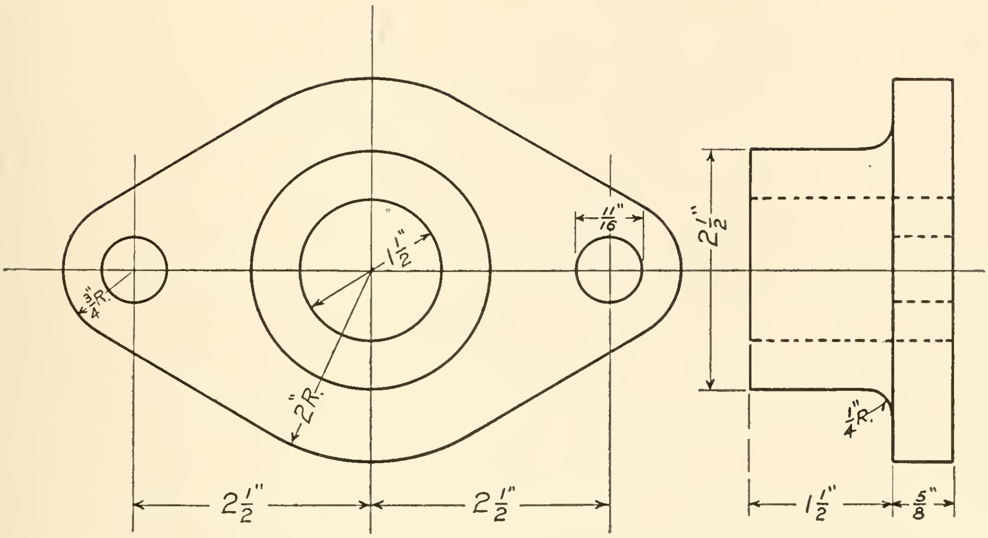


Fig. 13

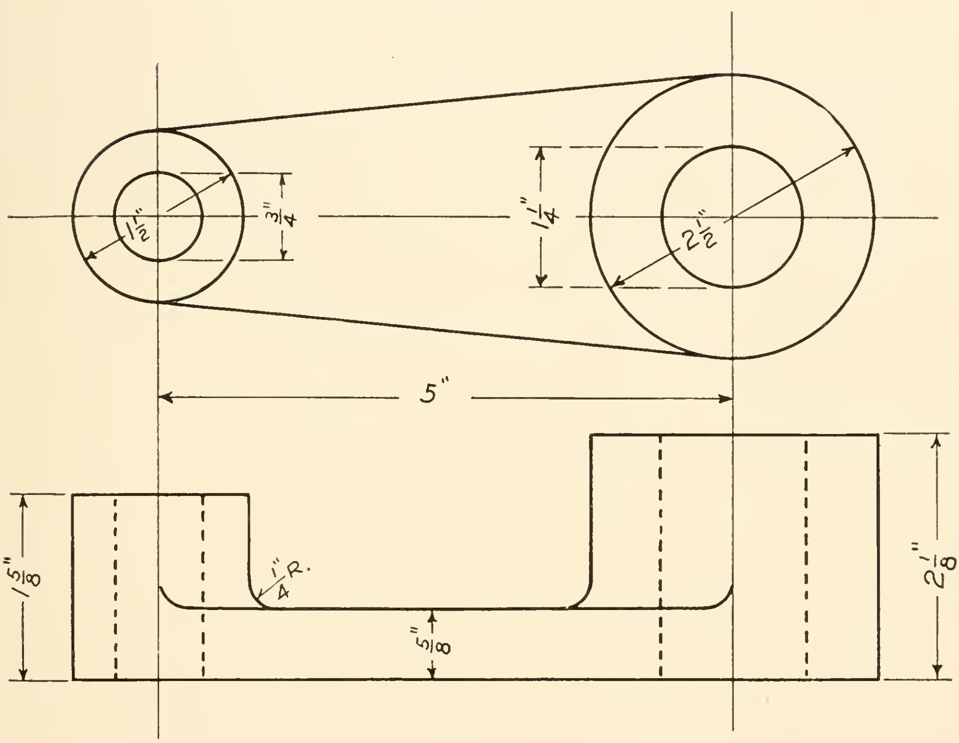


Fig. 14

Lay out three $1\frac{1}{2}$-inch circles tangent to one another (so that each circle touches the other two). Surround these circles by a tangent equilateral tri-

angle. "Line in" the triangle and test it for accuracy, using the large divider; the sides should be of equal length. Repeat this several times.

Lay out a full-size pencil drawing of the hexagon and square nuts shown in Fig. 12. In this problem the student will encounter three new features; one, the use of lines formed of short dashes, which are used to indicate a hidden surface; in this case, the untapped hole in the nuts. The other features are, the use of the circle to construct a figure, and the practice of laying out one view (in this case the top view) and from it projecting certain surfaces of the other views.

When laying out the top view of the hexagon nut, we first throw in the circle representing the diameter across flats ($3\frac{1}{8}$ inches), then with the **T** square and the 30°–60° triangle construct the outline. We follow the same plan for the square nut except that we use the 45° triangle with the **T** square in constructing the outline.

Make full-size pencil drawing of the stuffing-box gland shown in Fig. 13.

Make a full-size pencil drawing of the link arm shown in Fig. 14.

CHAPTER III

LETTERING AND FIGURES

Lettering. — When selecting a lettering system certain fundamentals should be kept in mind, such as simplicity and legibility. In other words, a type should be chosen that is simple and easy to construct freehand and which may be read easily and quickly, due to a certain individuality of the letters.

Many commercial drafting rooms, probably a majority, use the well-known Reinhardt system of lettering or some modification of it. Modern draftsmen are under obligation to Mr. Charles W. Reinhardt, the author of this system which has so largely displaced the mechanical abominations of twenty-five or thirty years ago.

When the student fully appreciates the fact that much of the information given on a mechanical drawing is furnished by means of printed notes, headings, titles, etc., he will come to a better realization of the importance of lettering in its application to this type of drawing.

The standards of the better drafting rooms are such that only lettering of excellent quality is accepted, for these firms take a legitimate pride in the fact that drawings bearing their name should convey an impression of high-class workmanship, which is in keeping with their manufactured products.

Figure 15 illustrates a simple analysis of the Reinhardt freehand system which is used throughout this text. A careful study of this illustration will show the order and direction of the various strokes used in forming these letters. The student should also study the proportions of the letters, especially noting

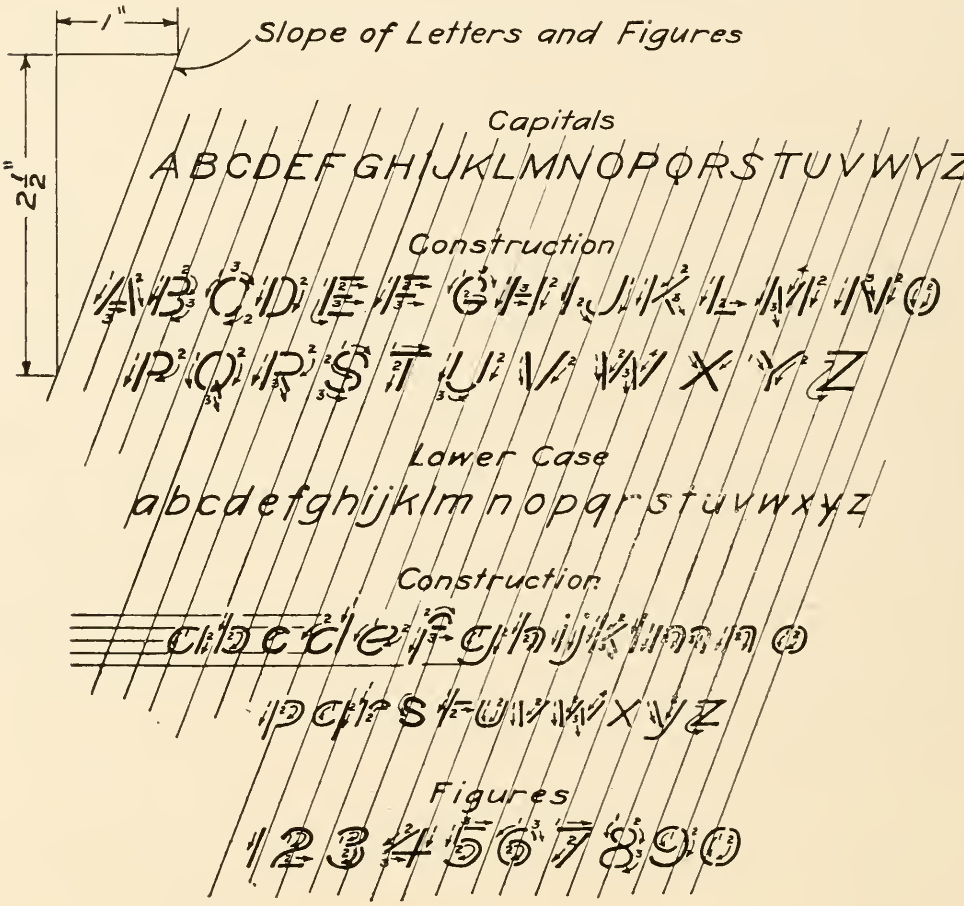


Fig. 15

those of the Lower Case, which are proportioned to take four spaces, two for the body of the letter and one space each above and below the body.

The use of guide lines, both horizontal and slope, as an aid in learning correct lettering should be encouraged, as these lines are very helpful and are

in fact a necessity for the beginner. These letters have a slope of from 1 to $2\frac{1}{2}$ as indicated by the little figure used as a guide for the slope lines. All of these guide lines should be light lines, distinct enough to be seen readily but to be decidedly secondary to the lines of the letters.

Figure 16 illustrates a little lettering triangle which most students can make for themselves out of a piece of an old **T**-square blade. This useful tool is proportioned to give the slope of from 1 to $2\frac{1}{2}$ so that it may be used to rule in slope guide lines.

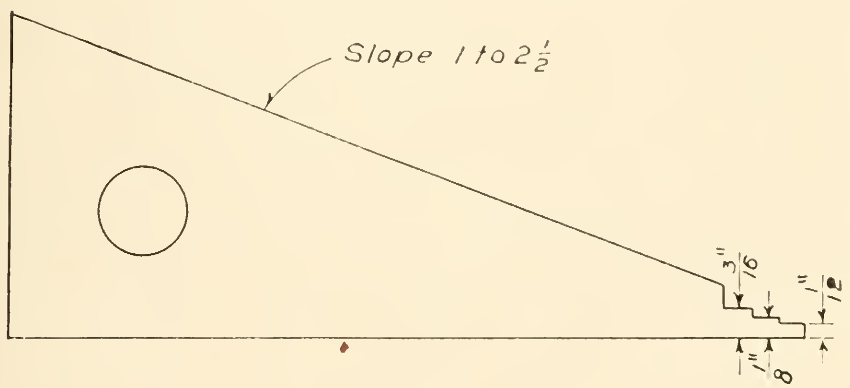


Fig. 16

The notches or steps at the tip are useful for ruling in the horizontal guide lines in the following manner: Place the triangle against the edge of the square blade (slope side up) with the pencil point against one of the steps, now slide *pencil and triangle* along the square blade and as the step holds the pencil away from the blade, the thickness of the step, the upper of two guides lines is produced, the lower guide line being ruled from the square blade. This device saves the time which would be required by using a scale to lay out the positions of the guide lines.

The thickness of the three steps represents the three heights used for the lettering in this text, $\frac{1}{12}$ inch for the body of the Lower Case letters, with $\frac{1}{8}$ and $\frac{3}{16}$ inch for the Capitals.

Care should be used in selecting a pencil for free-hand lettering; H, or 2H at most, should be used. If the pencil is too soft it will smear and the point will not last long; if too hard it will *cut into* the

Examples:

Note on Drawing....Make pattern to dash lines

Heading.......... BILL OF MATERIAL

Title.....WESTINGHOUSE ELECTRIC & MFG. CO.
PITTSBURGH, PA., U.S.A.

200 K.W. D.C. COUPLED GEN.
125 V. 8 P. 475 R.P.M.
ARMATURE ASSEMBLY

SCALE $\frac{1}{2}$ SIZE *DWG. NO. B 136254*

FIG. 17

paper and if just right the point slips over the paper as if greased.

The capital letters are used mainly for all titles and headings, while the lower case are used for all notes on drawings. Figure 17 gives certain examples which illustrate their use in practice.

Figures. — What has been written in regard to lettering applies equally well to figures. It is of great importance that the student should learn to make his figures so well that no one should have any trouble to read them easily and quickly. Mistakes

in construction are frequently caused by poorly written figures on drawings, and these mistakes are often very costly. The value of using great care at all times in placing the dimensions on drawings is thus clearly shown.

Problem. — Take a sheet of 11×15 inch drawing paper and divide the length into three parts of 7, 5 and 3 inches. Leave a space 1 inch wide across the bottom for a title strip. Head the 7×10 inch rectangle on the left, Capitals, the center one, Lower Case, and the one on the right, Figures.

Now rule in horizontal guide lines spaced as follows: Capitals, $\frac{1}{8}$ and $\frac{3}{16}$ inch, half of each; Lower Case, $\frac{1}{12}$ inch for the body and $\frac{1}{24}$ inch above and below the body; Figures, $\frac{1}{8}$ inch for the whole numbers and $\frac{1}{4}$ inch for fractions, show several rows of whole numbers, some of fractions and some mixed whole numbers and fractions. Now rule in slope guide lines over the whole sheet.

When practicing these letters and figures follow the strokes in the order illustrated in Fig. 15. Use care when printing the fractions, that the parting line shall touch neither figure; both should stand out clear and distinct.

CHAPTER IV

ELEMENTARY PERSPECTIVE

Perspective. — An elementary knowledge of perspective drawing will be of value to all students as a preparation for the study of Orthographic Projection. It will also be found useful as a stimulant for the reasoning faculties, as the problems given cannot be drawn correctly unless a reasonable amount of thought and study is devoted to them. A little knowledge of this subject will also be helpful in sketching pictorial representations of objects.

When a picture of a natural object is drawn on a plane surface in such manner as to represent that object as it would appear to the eye (when seen from a single view-point), it is said to be drawn in perspective.

In theory there is a transparent plane (usually vertical) between the eye and the object. The cone of rays from the eye to the object intersects this plane, and if these points of intersection are connected, the result is a smaller outline upon the picture plane, which is a duplicate of the view seen from the station point of the eye.

When this object is shown with its vertical surfaces forming an angle with the vertical plane which lies between the eye and the object, it is termed angular perspective. If the object is a rectangular figure and these vertical surfaces form equal angles

with the plane as illustrated by the top view of the block shown in Fig. 18, it is termed 45° perspective, from the fact that this is the angle formed by each front surface with the plane.

In so far as the subject of perspective drawing is dealt with in this book it should be understood that we are referring to 45° *perspective only*, as it is not

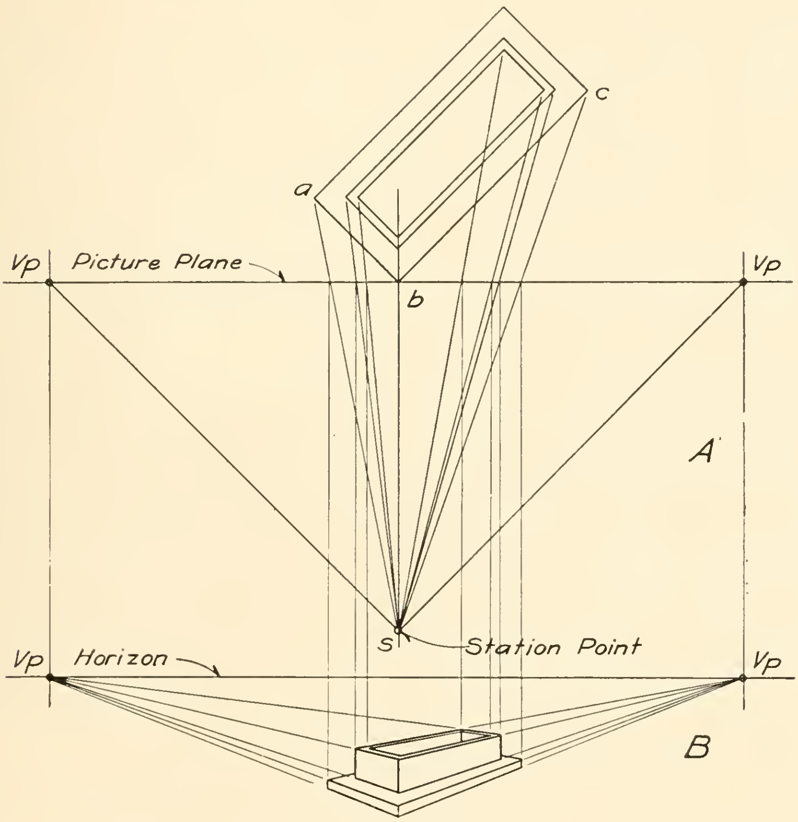


Fig. 18

essential to our purpose to go into this subject more extensively at this time.

Certain well-known phenomena of perspective which should be noted and kept in mind by the student, when making perspective drawings, are as follows: The horizontal lines of an object converge toward points on the horizon, which are termed the

vanishing points. The *horizon,* or *horizon line,* is a neutral line on a level with the observer's eye, or the *station point.* Horizontal lines in the object above the horizon appear to incline downward toward it, while those horizontal lines below the horizon appear to incline upward toward it. Horizontal lines which are parallel converge to the same vanishing point. Vertical lines in the object remain vertical in the perspective drawing. The dimensions

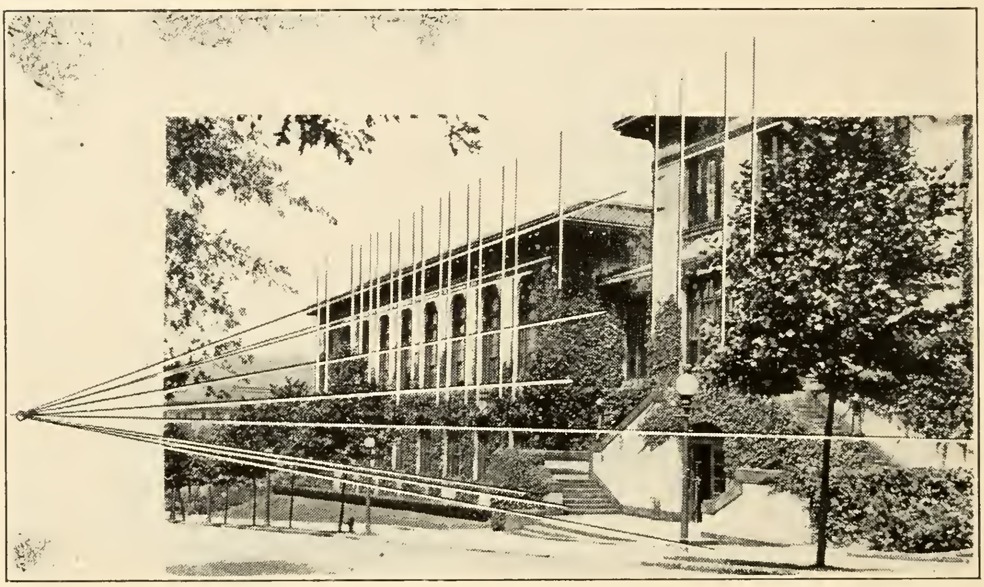


Fig. 19

of an object diminish with the increase in the distance *away* from the observer.

Most of the phenomena just mentioned may be observed in the illustration of the building in Fig. 19, which photographic view was taken from a point on an axis with the near corner, from a height on a level with the horizon line.

While the vanishing points in most of the problems given are determined, having been assumed, it is,

well for the student to be familiar with a method of locating these points correctly for angular perspective, which is frequently called "two-point perspective" from the fact that all horizontal lines converge to two vanishing points.

At *A*, in Fig. 18, is shown a top view of an object with one corner touching the line or trace which represents the vertical picture plane. The edges *ab* and *bc* form equal angles with the picture plane. At *S* is located the station point of the observer's eye; the distance that *S* is placed from the picture plane is a matter of judgment; if too near, the proportions of the picture are not pleasing, and if placed too far away, the picture may be too small or the vanishing points may be entirely off of the drawing board.

Having assumed the station point, draw lines from *S parallel* to *ab* and *bc* through the picture plane; the vanishing points are located to the right and left, at distances thus found, from the axis *Sb* which is perpendicular to the picture plane.

At *B*, in Fig. 18, is shown the view of the object seen through the picture plane from the station point *S*. This illustration also shows one method of finding the correct length of the horizontal lines of the figure.

Another method of finding the proportions of figures is shown in Fig. 20, and as this is the method which we shall use it is important that it should be studied carefully. This "perspective scale" has as its basis a *one-inch cube*, which is to be used as the basis when drawing the problems pertaining to this subject.

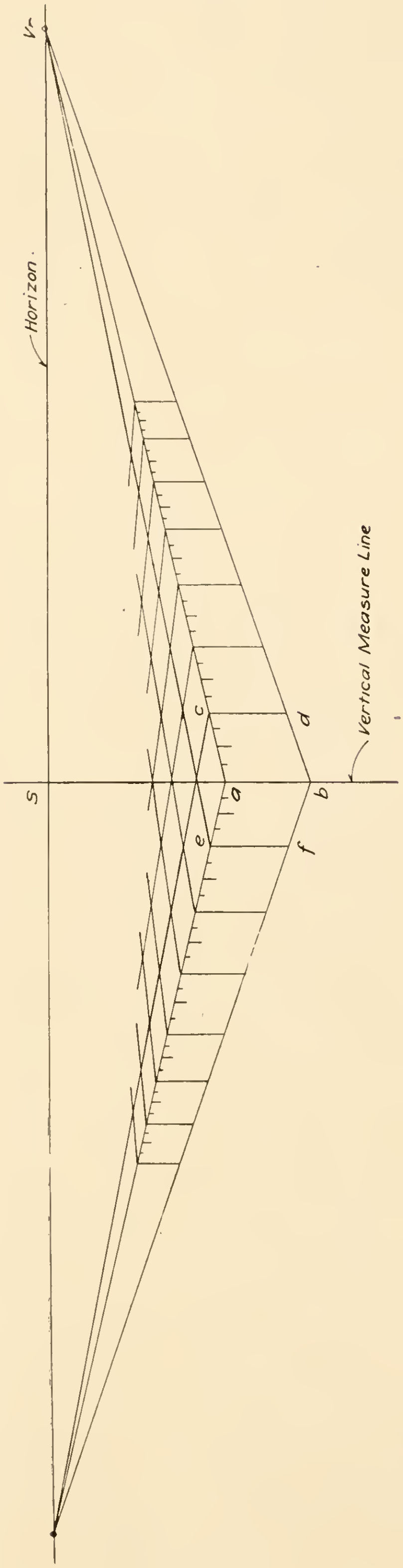


Fig. 20

In so far as we treat perspective, the "vertical measure line" is the *only* line on a perspective drawing upon which we may lay off actual dimensions. If the student will think of a point as an end view of a line, and will refer to *A* of Fig. 18, he will understand why measurements may be made on the vertical measure line only. Point *b* in this illustration is an end view of the vertical measure line, and when we represent all surfaces back of this point we must foreshorten these lines to give the true perspective effect.

When determining the proportions of the basic cube, Fig. 20, point *a* being assumed at a definite position below the horizon, lay off dimension *ab* equal to one inch upon the vertical measure line, from points *a* and *b* draw light construction lines converging on the vanishing points, now *by eye* locate line *cd* which forms the fourth side of one of the square surfaces of the cube. Do this by using trial lines,

until the impression upon the eye is satisfactory. Line *ef* is formed in the same manner as *cd*.

If we assume that line *ac* equals one inch *in perspective,* half of this line, *divided by eye,* equals one-half inch; this half inch may be divided into quarter inch spaces in the same manner, and so on to as small dimensions as may be desired.

The circle in perspective is an ellipse, and the illustration, Fig. 21, shows at *A* the use made of the square as an aid in its construction. This method has the merit of simplicity and is applicable

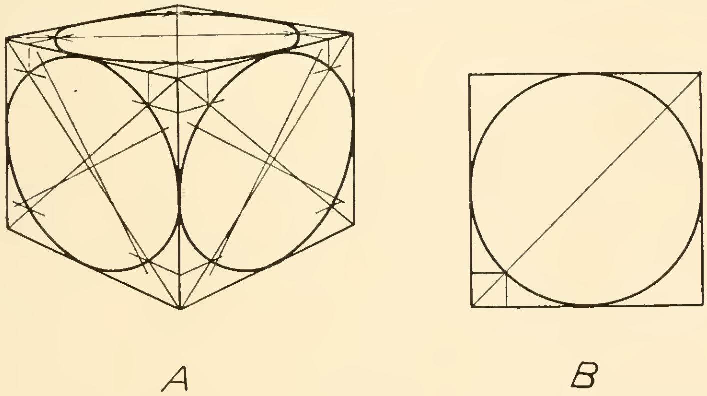


Fig. 21

to a variety of figures wherein the circle or semi-circles are used.

In addition to the four tangent points at the sides of the square, four more points may be located on the diagonals by means of the method indicated at *B*, Fig. 21.

When throwing in a radius to form these circles in perspective the compass may be adjusted until the radius is suitable to strike three of the eight points mentioned, preferably one of the small radii which cuts a diagonal point and two sides of the square, thus forming the small ends of the ellipse first.

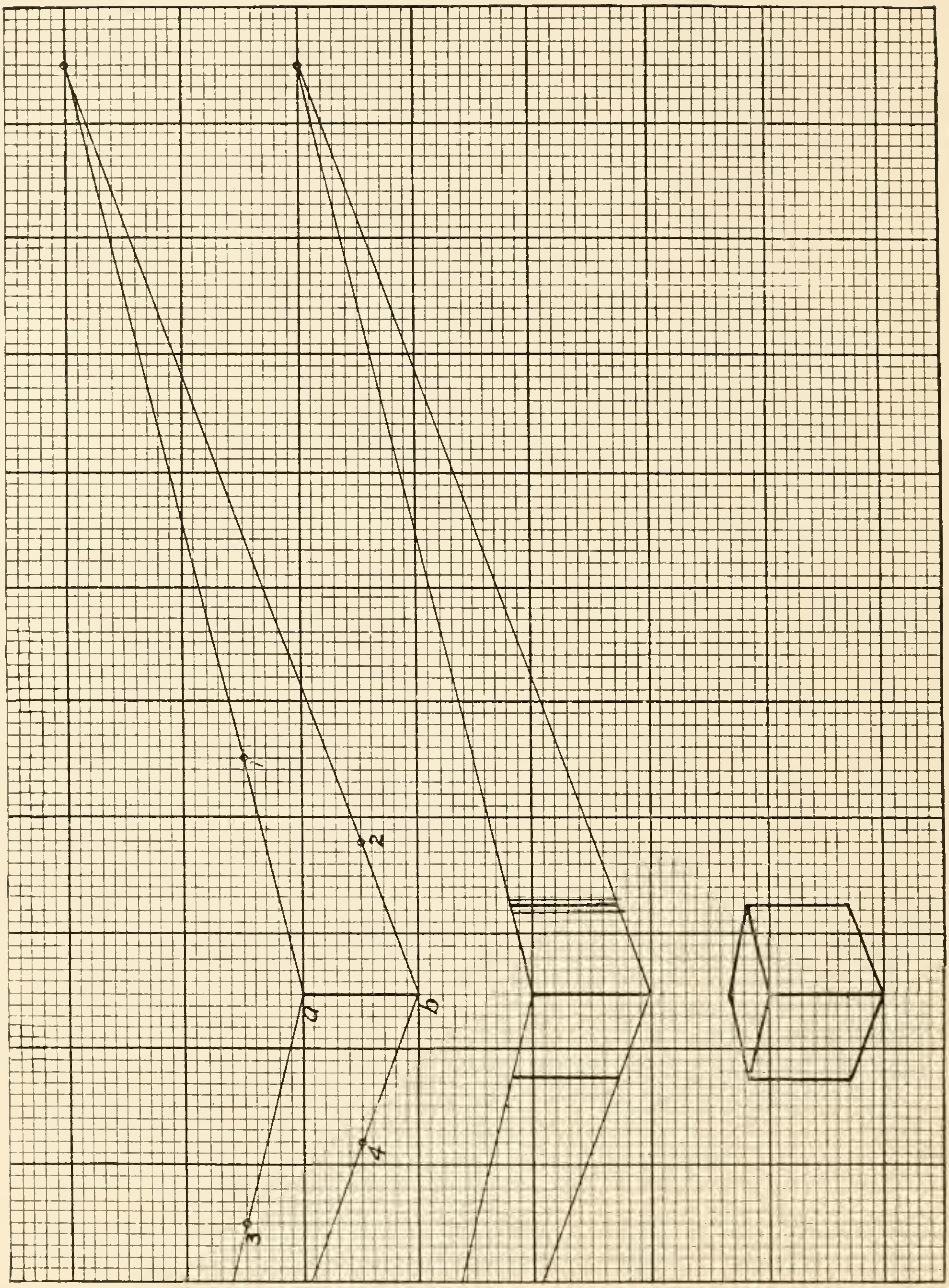


Fig. 22

The student should note that the major and minor axes of the ellipse do not coincide with the diagonals of the square.

In taking up the problems which follow it is desired that these perspective drawings shall be made on a *cross-section pad,* as all of the problems have been

planned with this aim in view. It is further desired that *one* vanishing point *only* be shown, the lines which would converge on the missing vanishing point being located in their proper positions by the method indicated in the illustration, Fig. 22.

Figure 22 illustrates the various stages of construction when laying out a cube in perspective. Having located line *ab* and drawn in the converging lines from *a* and *b* to the vanishing point, choose a point along the line to the right from *a*, as at 1, where the converging line happens to pass the intersection of two of the lines of the cross-section pad, locate the corresponding point at the left by means of the cross-section lines as at 3, draw a line from *a* through point 3, and we have two lines leaving point *a* which form equal angles with the horizontal line through *a*. Points 2 and 4 with converging lines are located as above described but it should be noted that the angle formed by *b*2 with the horizontal line through *b* is greater than that formed by *a*1 with the horizontal line through *a*, due to the fact that *b* is located lower than *a* from the horizon.

The other features of the illustration, Fig. 22, should be readily understood from the explanations previously given.

Problems. — In laying out the following problems the student is not restricted in the use of tools but may use any portions of his equipment desired. Care must be taken to complete these drawings neatly and accurately.

Lay out a one-inch cube in three different positions below the horizon; one inch, one and one-half inch,

and two inches, from the horizon to the top corner marked *a* in Fig. 22. In each case the vanishing point shown is assumed to be eight inches to the right of the vertical measure line. Place all three cubes upon the same sheet of cross-section paper.

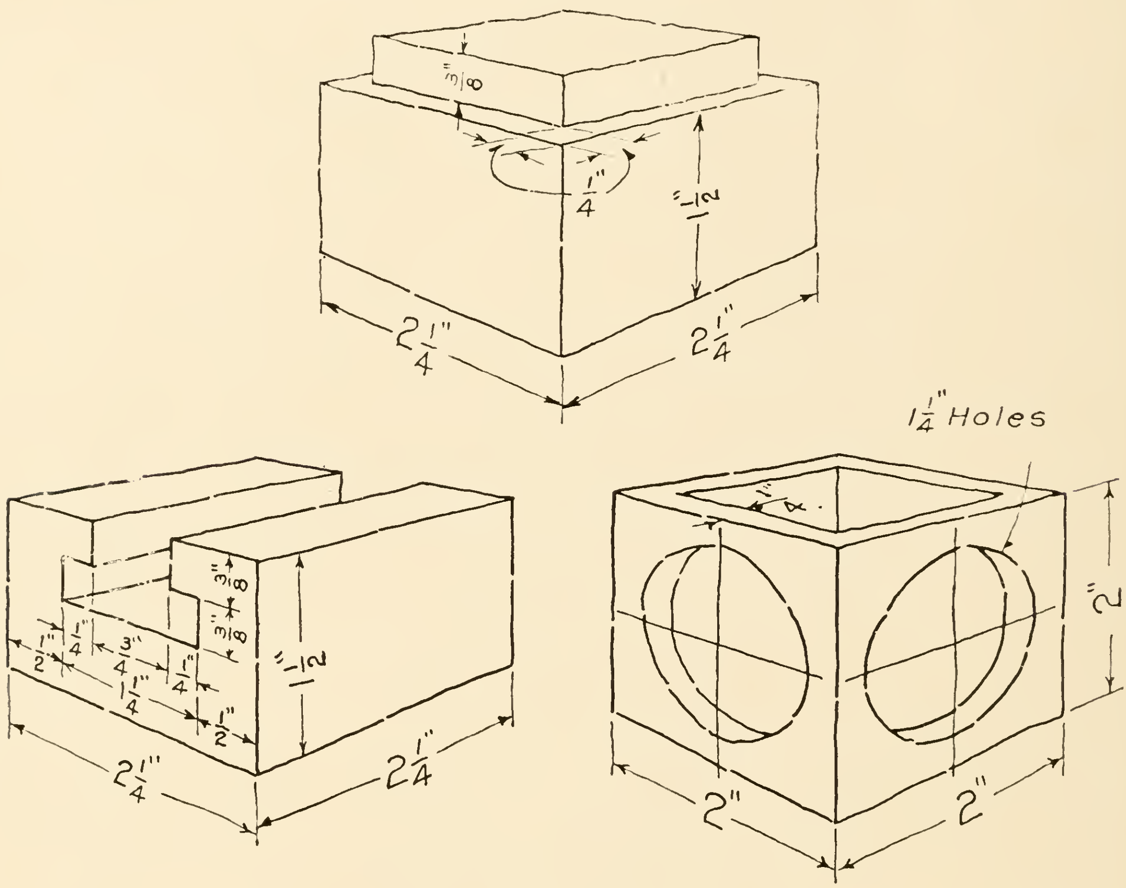


Fig. 23

Assuming a position two inches below the horizon, and using one vanishing point located eight inches to the right of the vertical measure line, lay out in perspective the objects shown in Fig. 23. Take each object in the order of simplicity, placing but one figure on a sheet of cross-section paper.

CHAPTER V

ORTHOGRAPHIC PROJECTION

Orthographic Projection. — In the presentation of perspective drawing we directed the student's attention to such basic features of the subject as the relative positions of the object, the picture plane and the eye. Attention was also called to the cone of rays, from the eye to the object, which intersected the plane. Before taking up the study of orthographic projection we again refer the student to those features of perspective drawing as we wish them kept clearly in mind, so that *by comparison* we may convey a clear understanding of the fundamentals of orthographic projection.

By referring to the illustration of perspective drawing in Fig. 24, it will be noted that there is but *one plane* used, and that the rays, or projectors, from the eye may form *any angle* with the plane. Further it should be noted that in this perspective drawing we have *one view* showing *three surfaces* of the object.

Under the rules of orthographic projection we may use as *many planes* as desired, *one* for *each surface* we wish to portray, but there is this basic difference between the position of the picture plane in perspective and that in orthographic projection. In perspective the plane may be placed in any position we choose, and may *form any angle* with the object,

but in orthographic projection (while the plane is between the eye and the object as in perspective) the plane *must* be located *parallel to* and *adjoin* the *surface* to be shown.

There is another basic difference between the two methods, perspective and orthographic, to which we

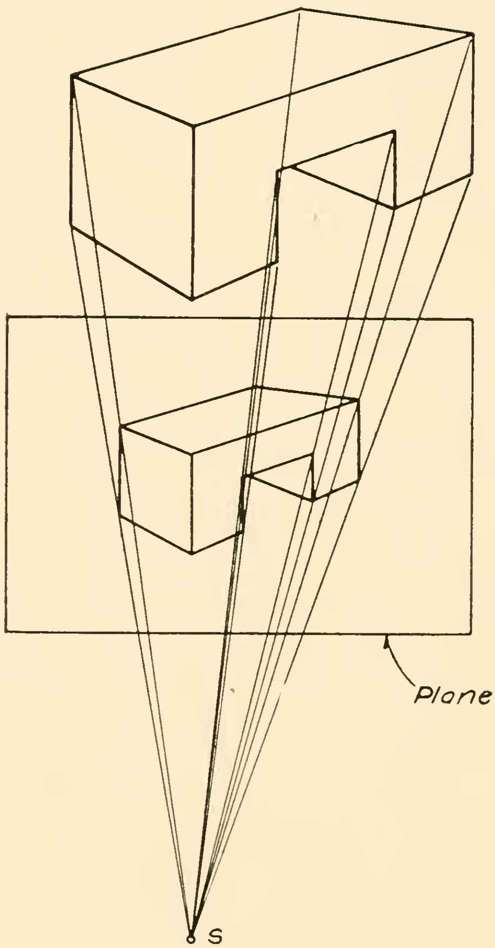


Fig. 24

wish special attention paid, and this is the angle with the plane formed by the projection lines or rays. As previously stated these lines in perspective may form any angle with the plane, while in orthographic projection they *must always* be at right angles with the plane.

To restate these fundamentals briefly, when making orthographic projection drawings, the plane is placed *parallel* to and *adjoining* the surface to be projected, the projection lines perpendicular to the

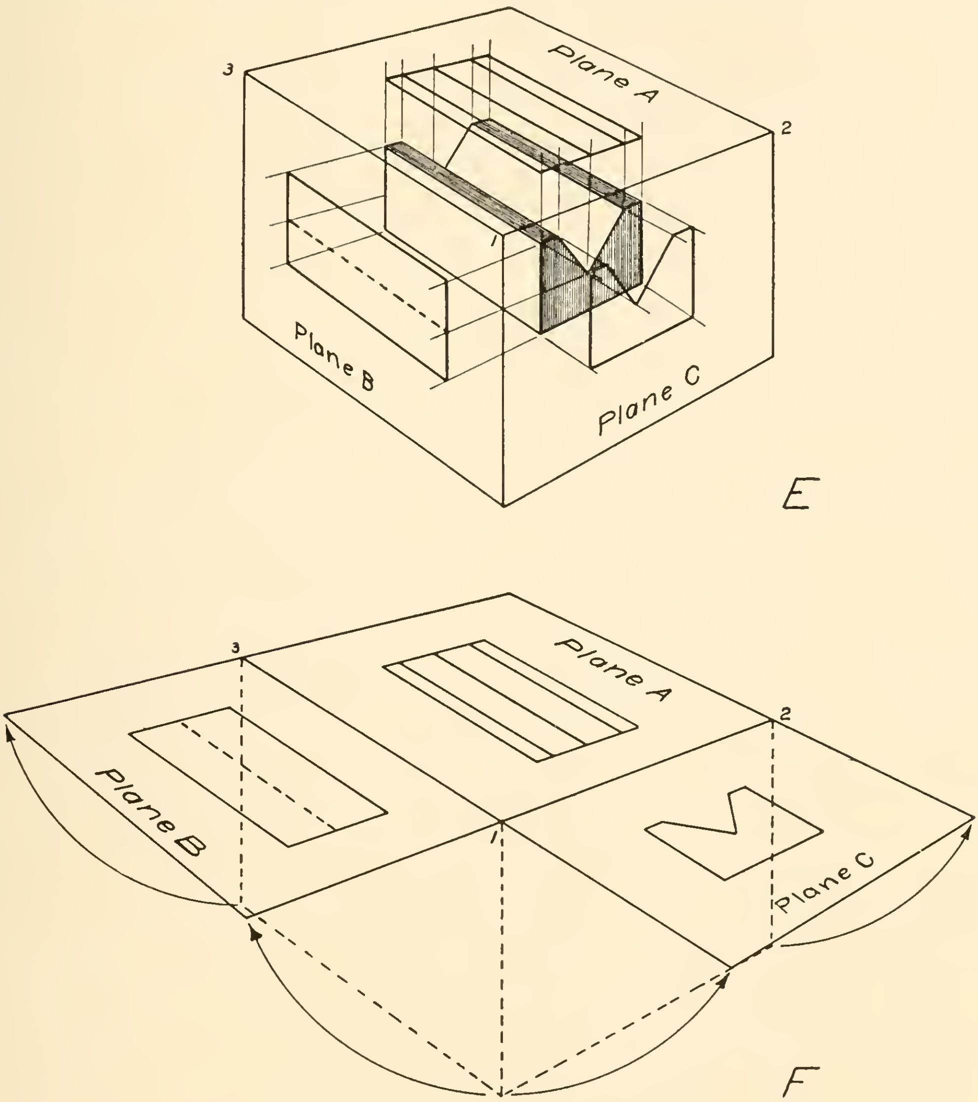


FIG. 25

plane are projected *out* from the object to the plane, and the number of planes used depends upon the number of surfaces which it is necessary to show to convey a clear understanding of the *shape* and the *size* of the object.

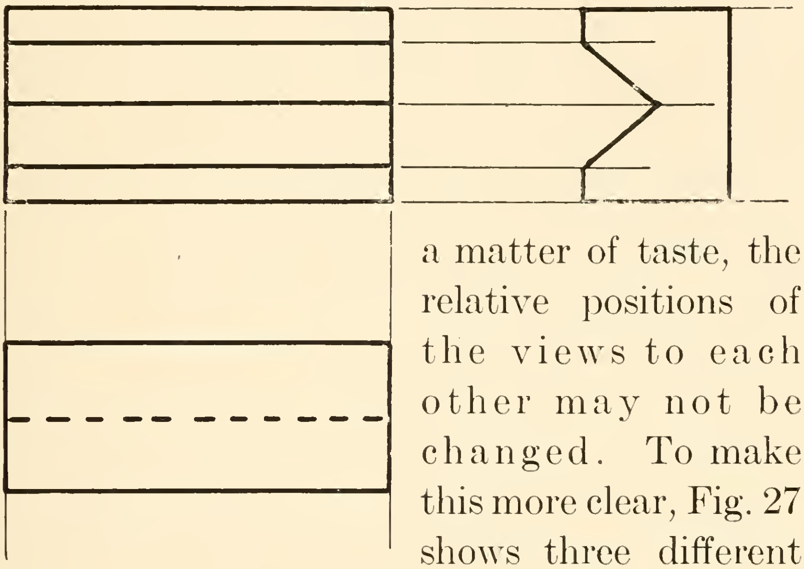
As an aid in presenting the theory of orthographic projection the illustration Fig. 25, at *E*, represents three planes placed parallel to three surfaces of an object. Upon plane *A* is projected the top view, upon plane *B* the side view and upon plane *C* the end view of the object. These planes placed in this manner lie in positions which are at right angles with each other, consequently from a view-point which is perpendicular to one of the planes, we cannot see the views upon the adjoining planes; it thus becomes necessary to revolve these two planes so that all three views may be studied from the same position at the same time.

For convenience we may assume that plane *B* is hinged to plane *A* along line 1–3 and that plane *C* is hinged to plane *A* on line 1–2. Now we may revolve planes *B* and *C* up into the same plane as plane *A* in the manner indicated at *F* in Fig. 25; by this means all the views of the object may be observed and studied at the same time.

Figure 25 illustrates the theory of orthographic projection which is, or should be, in the mind of a draftsman when he makes a three-view mechanical drawing of this object. In practice the planes are not shown, though for certain types of drawing we frequently show a line or trace to represent the planes; in general one view is laid out first (usually the view which can be utilized to the best advantage to help lay out the other views), and from this view are thrown out projection lines as aids in constructing the other views as shown in Fig. 26.

From the foregoing the student should realize that

in laying out mechanical drawings in accordance with the rules of orthographic projection, the *relation* between the views is fixed definitely, that while the *arrangement* of the views on the drawing paper is



a matter of taste, the relative positions of the views to each other may not be changed. To make this more clear, Fig. 27 shows three different

Fig. 26

arrangements of the views of an object, but the relative positions of the views to each other are not changed at all.

Auxiliary Planes. — In the majority of cases the projection planes are parallel with vertical or hori-

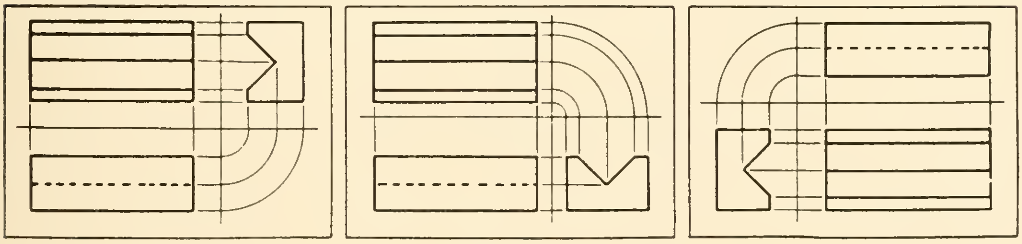


Fig. 27

zontal surfaces of the object to be drawn, but it frequently happens that there are certain surfaces on the object which do not lie parallel with either of these planes consequently a surface of this char-

acter would be represented by a foreshortened view if shown on either a vertical or horizontal plane.

When an occasion of this kind arises it is necessary to use an auxiliary plane placed parallel to the surface, so that we may project this view in its

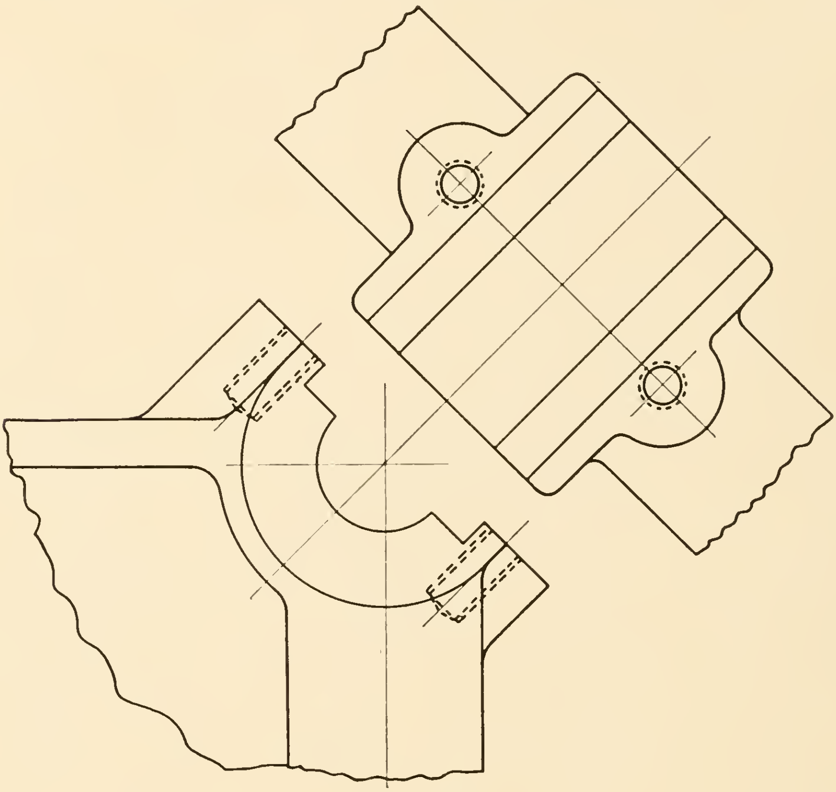


Fig. 28

true dimensions as indicated by the illustration in Fig. 28.

Reading Drawings. — The ability to read an orthographic projection drawing presupposes a training which enables one to gain a clear understanding of the shape and the size of an object. This understanding is gained only after studying the various views of this object shown on the drawing. To acquire this ability it is necessary to stimulate the imagination as an aid in developing the faculty for

mental picturing, for without this power we may never be able to read drawings intelligently.

When forming mental images of objects our natural tendency is to think of these mental images in perspective form; this is due to life-long habits formed from always viewing objects in this fashion. One of the reasons for presenting certain problems in perspective form is due to a desire to take advantage of this tendency. Another reason is that when a student is forced to translate perspective drawings into orthographic drawings he is obliged to use his reasoning faculties, as there is no chance to copy and it is only through the exercise of a fair knowledge of the fundamentals involved that the problems may be solved.

The problems referred to will be taken up in the next chapter under the head of freehand drawing.

CHAPTER VI

FREEHAND SKETCHING

Sketching. — When an engineer is planning some form of construction, he must have the ability to put his ideas on paper in the form of freehand sketches. These sketches may be orthographic drawings made freehand, which represent certain views of his creation, or they may be pictorial representations. In either case he must possess the power to transmit to paper the mental image of his creation.

A new design does not spring fully developed from the engineer's brain but is the result of much thought and careful study; consequently these freehand drawings are a distinct aid in the development of the design, as they are something tangible which may be shaped and changed to suit the will of the designer.

When attempting to convey an idea regarding some mechanism or some form of construction, the freehand sketch is one of the commonest methods of presenting such matter to those engaged in engineering work. Sketches made in the shops form the basis for many of the working drawings and much of the repair work in manufacturing plants.

Method. — To make sketches which clearly represent our ideas it is essential that there shall be excellent coördination between the eye and the hand, so that these servants of the mind may be made to perform our will. It is also of importance to

choose a method of making sketches which is simple and readily acquired.

The method we shall follow is called the "Short-stroke Method," from the fact that as we draw a line in any direction, it is not made by a single stroke of the pencil, but by a series of short strokes. The object of using these short strokes is to enable the student to correct an error in direction at any point along the line. The result is that the general direction of the line is straight, and though there may be slight errors along the line, they cause no doubt as to its meaning.

The following suggestions will be found helpful if studied and carefully followed: As mentioned in Chapter No. 2, a pencil of H or 2H hardness sharpened to a round point (not too sharp) will be found generally satisfactory. Learn to hold the pencil easily and naturally between the first and second fingers and the thumb, never hold it in a stiff or cramped manner.

Do not turn the paper to suit the direction in which a line is to be drawn, but fasten it down to the drawing board and try to develop that freedom of movement of fingers, wrist and arm which will enable one to draw with ease a line in any direction.

The student should sit upright when drawing so that he may get a clear view of his work as a whole. By having the head well up over the work, the eyes can direct the movements of the pencil better, as they are in a better position to see if the desired shape is growing under the pencil, than if held close to the work.

In drawing straight lines, as illustrated in Fig. 29, the student should note that lines drawn in certain directions are made by a wrist movement, while in other directions a finger movement only is used.

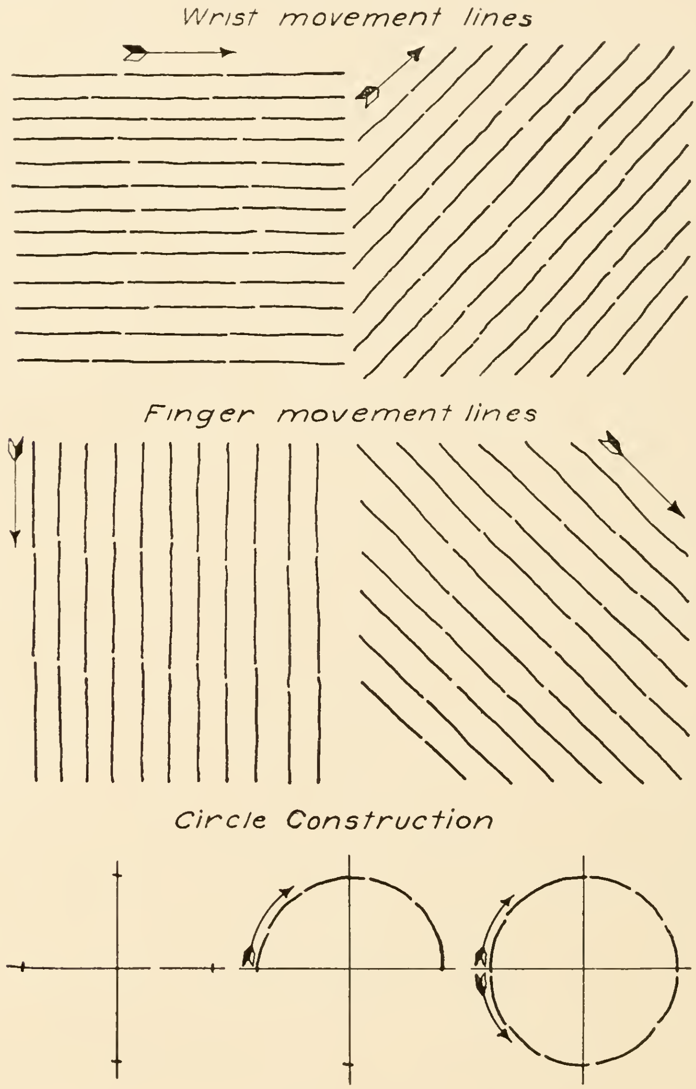


Fig. 29

Construction lines and points are of considerable aid in drawing circles, as indicated by the three stages of drawing a circle shown in Fig. 29. Partially laying out a sketch in light construction lines and then lining in is also helpful.

Proportions. — It is a valuable acquirement, when sketching, to be able to make the details of a drawing of the proper proportions in relation to each other. The scale of the sketch is of little importance, provided it is large enough to show clearly the piece or pieces we desire to illustrate, but it is of importance that the various parts of an object, or the different views of a drawing, shall be drawn to the same scale. To obtain this result it is quite necessary that the student should train his faculty of perception so as to have a well-developed sense of measurement, this sense not being confined to linear measures only but should include angular measurements as well.

The usual procedure when making a sketch of an object is, first, to determine what views are necessary, then to draw these views completely; next, to decide on the dimension lines to suit these needs, and, finally, to obtain these dimensions and place them on the views of the sketch.

Problems. — The problems which follow should be drawn *freehand* on *cross-section pad;* neat, clear sketches are desired, using the "short stroke" method of making lines. Place all dimensions given upon the orthographic projection sketches, but leave off the dimensions from those problems which are to be drawn in perspective.

Make two-view orthographic sketches of the following: A 2-inch cylinder 4 inches long, a prism $2\frac{1}{4}$ inches square and 4 inches long, a hexagonal prism $1\frac{3}{4}$ inches *across flats* and 4 inches long, a triangular prism with 2-inch sides and 4 inches long, a hex-

agonal pyramid 2 inches *across flats* at the base and 3 inches in height.

Make a neat perspective sketch of each of the objects shown in orthographic in Fig. 30.

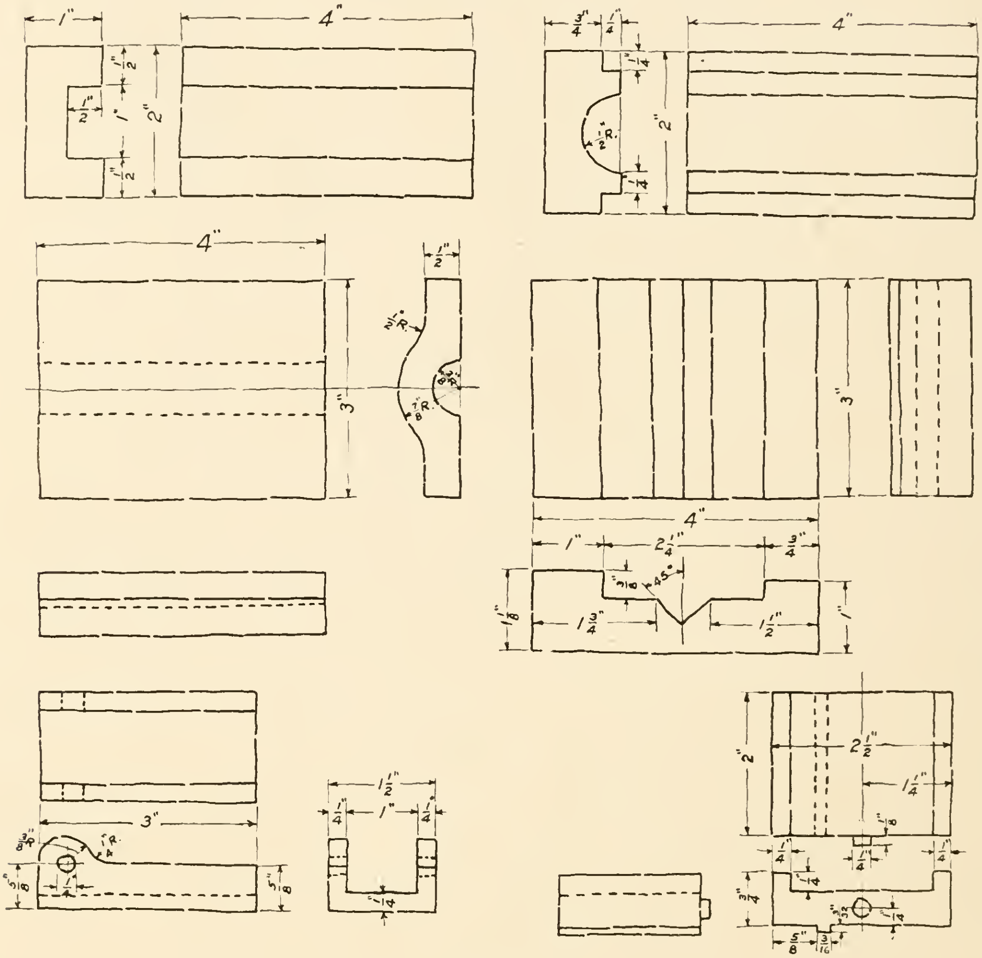


Fig. 30

Make a three-view orthographic sketch of the clamp shown in Fig. 31.

Make a three-view orthographic sketch of the shaft support shown in Fig. 32.

Make a three-view orthographic sketch of the tool rest shown in Fig. 33.

Make a two-view (side and edge) orthographic

sketch of the pulley described below, the edge view to show hub and arms by means of hidden surface lines: Diameter of pulley 14 inches at crown; taper

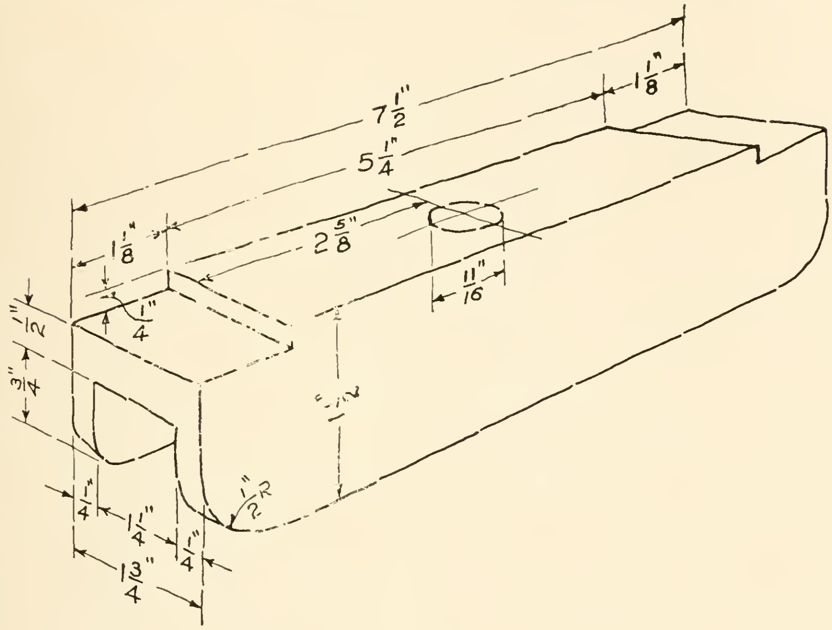


Fig. 31

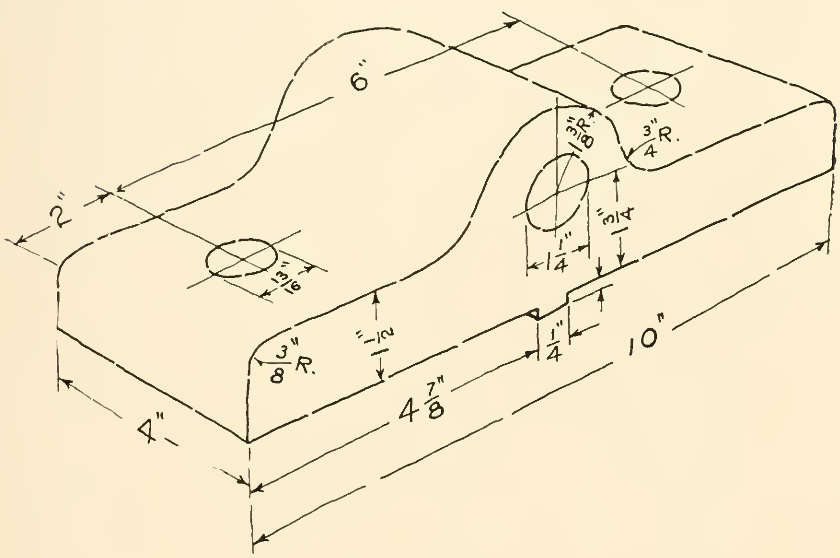


Fig. 32

of crown equals $\frac{1}{4}$ inch per foot; face or width 6 inches.

Diameter of hub $3\frac{3}{4}$ inches; length of hub 4

inches; bore $1\frac{7}{8}$ inches; keyway $\frac{7}{16}$ inch wide by $\frac{3}{16}$ inch high.

Rim made with rib around inside where joined to arms. Rim $\frac{1}{4}$ inch thick at edge, $\frac{9}{16}$ inch thick through crown and rib; inside of rim straight to arms.

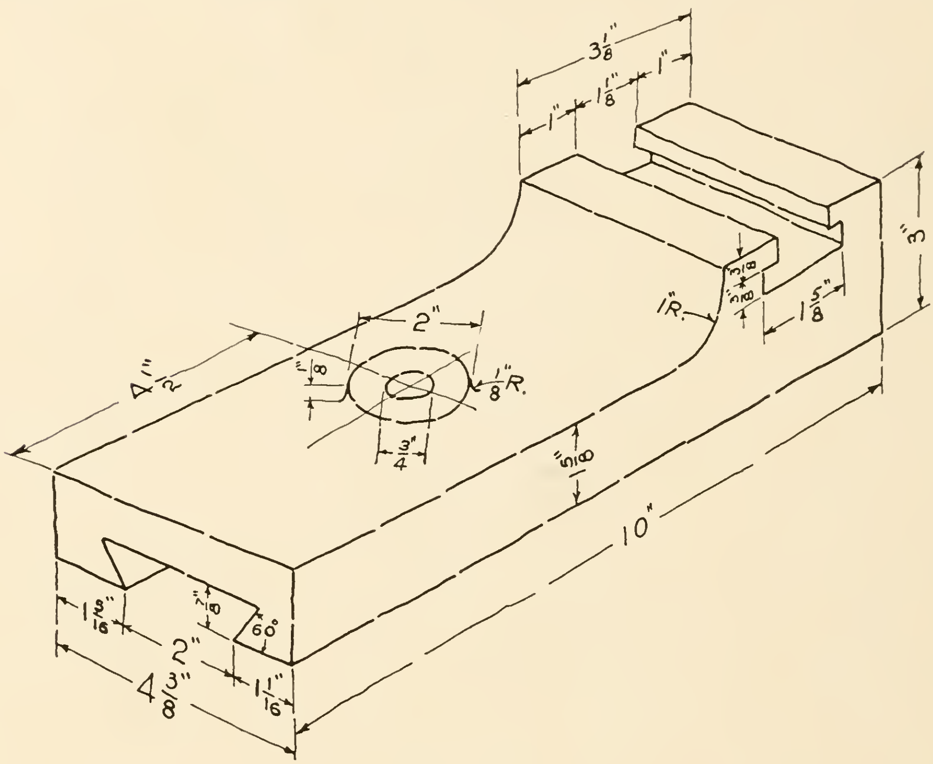


Fig. 33

Number of arms 6; arms $1\frac{1}{4}$ inches wide by $\frac{5}{8}$ inch thick at rim, and $1\frac{5}{8}$ inches wide by $\frac{13}{16}$ inch thick at hub; $\frac{1}{4}$-inch fillets (or rounded corners) at side of arms at hub, and at side and edge of arms at rim; $\frac{5}{8}$-inch radius at junction of edge of arms near hub.

CHAPTER VII

ENGINEERING CURVES

Engineering Curves. — The curves illustrated in this chapter are in very common use in engineering work, consequently it is desirable to make a brief study of the methods of construction. In presenting these methods of construction it should be appreciated that there are other methods "just as

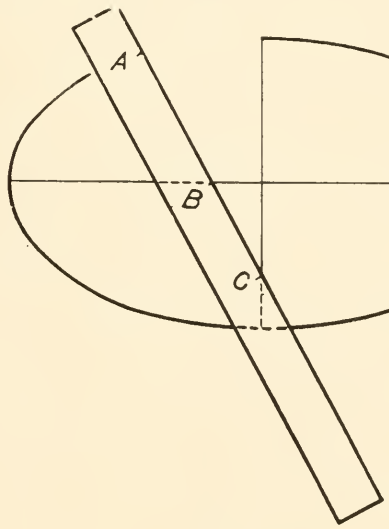


Fig. 34

good" and that the methods chosen happen merely to be popular ones.

Ellipse. — The ellipse has been seen previously in the chapter on Perspective, as it is the circle viewed obliquely. Four methods of constructing the ellipse are shown, of which Figs. 34 and 35 are correct and true mathematically, while Figs. 36 and 37 are near approximations which are very

convenient and satisfactory methods for use under certain conditions.

Assuming a major, or long, axis of $3\frac{1}{2}$ inches and a minor, or short, axis of 2 inches for Fig. 34, lay off these axes to the lengths given; take a straightedge or scale and on one edge mark off the points AB equal to half the minor axis; from A mark off point C equal to half the major axis. Place the straightedge so that point B comes on the major

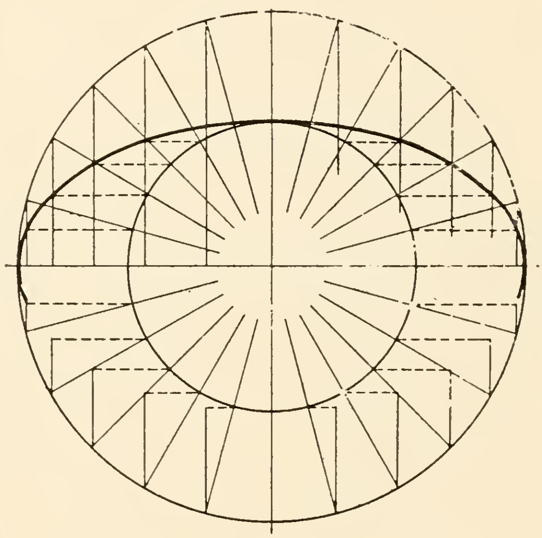


Fig. 35

axis and point C on the minor axis; now, with the pencil, mark a point on the drawing paper at A. Shift the straightedge and repeat (keeping B and C on the major and minor axes respectively), placing a sufficient number of points on the paper to enable one to trace a curve through them easily.

The method illustrated in Fig. 35 is one of the simplest; the diameters of the circles shown are equal to the lengths of the major and minor axes. To locate a point on the ellipse, draw a radial line

from the circle center cutting these circles; where this radial line intersects the major circle drop (or raise as the case may be) a vertical line, from the intersection of the radial line with the minor circle throw out a horizontal line; the intersection of this horizontal line with the vertical line from the major circle is the desired point on the curve of the ellipse.

At Fig. 36 is shown the "three-radii" approximation which is constructed as follows: Construct

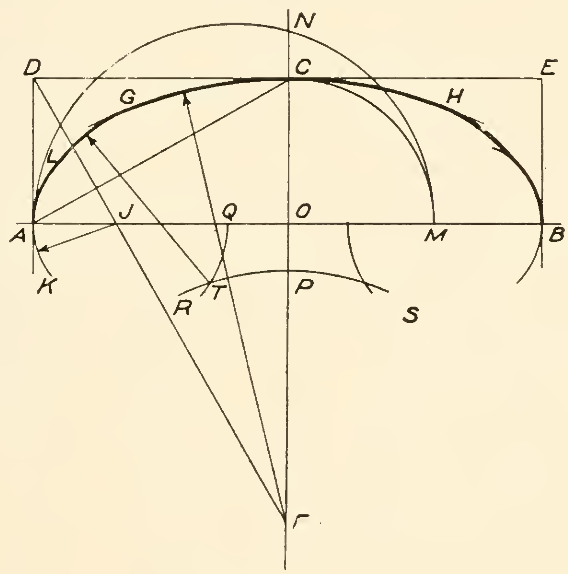


Fig. 36

the rectangle *ADCEB*. Draw the diagonal *AC*. Through *D* draw *DF* at right angles to *AC*. Then *F* is the center for arc *GCH*, and *J* is the center for arc *KAL*.

Make *OM* = *OC*. Describe the semicircle *AM*.

Make *OP* = *CN*. With center *F*, describe arc *RPS*.

Make *AQ* = *ON*. Then, with *J* as center and radius *JQ*, describe arc intersecting arc *RPS* at *T*. *T* is the center for the tangent arc *LG*.

To construct the elliptical curve shown at Fig. 37, divide the base lines of the curve into the same number of equal parts (any number) and connect these division points by straight lines. The com-

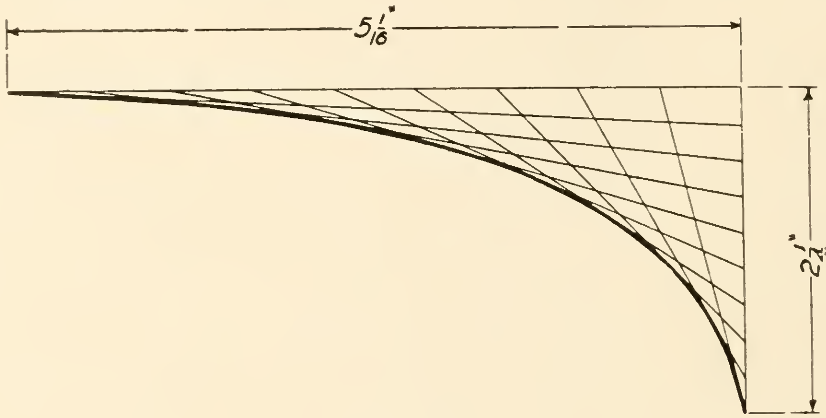


Fig. 37

bined outer surfaces of these lines form the desired curve.

Cycloid. — The method followed in laying out the following curves is based upon the principle of *generating the path of a moving point.*

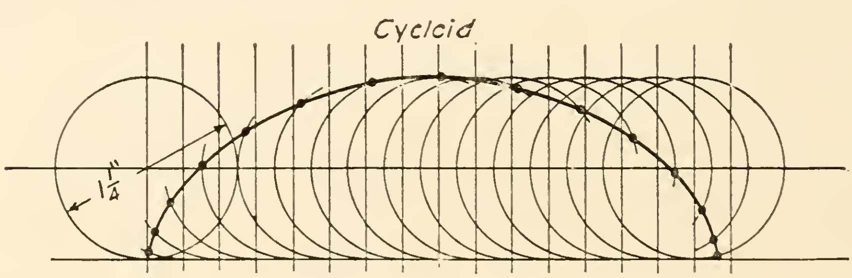


Fig. 38

The cycloid is the curve generated by a point which is located on the circumference of a circle when this circle is rolled along a straight line. When the generating circle is rolled *upon* another circle, an epicycloid will be generated. When the gen-

erating circle is rolled *inside* another circle, a hypocycloid will be generated.

To generate the cycloid mechanically, lay off the base and the center lines; set the dividers to any short space (so that the length of the chord is about equal to the arc), in this instance $\frac{1}{4}$ inch, and step off 16 or 18 points on the base line. Erect per-

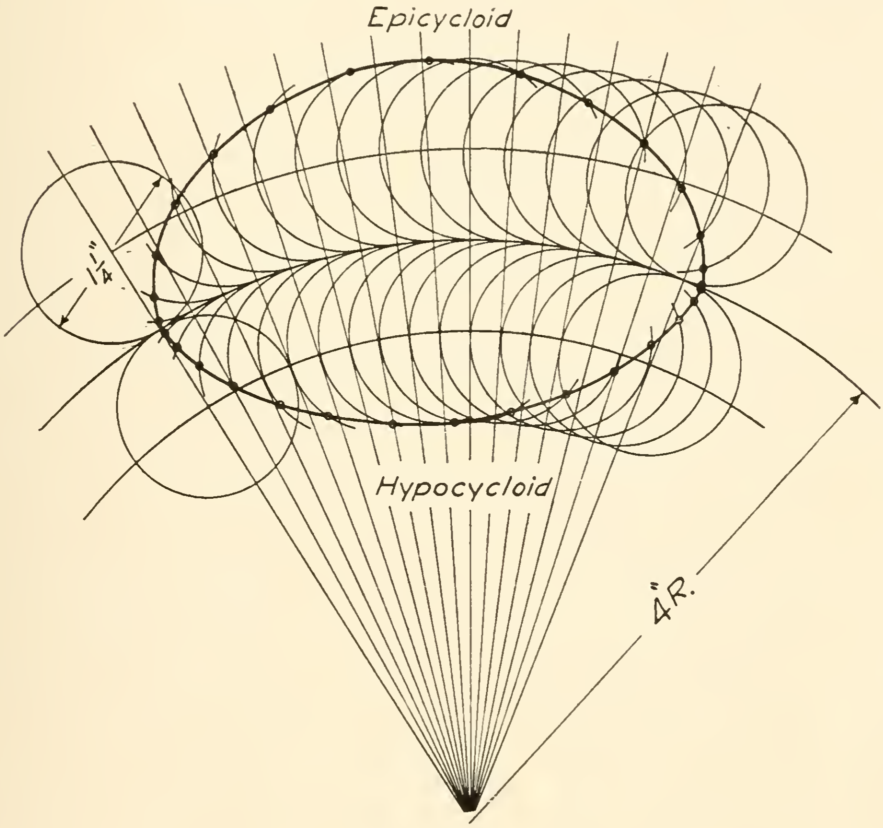


Fig. 39

pendiculars through these points; swing in the generating circle from these different points, so as to place the circle in the various positions which it would assume in making one complete revolution. Now, with the dividers, step off on the second circle the distance it has rolled along the base line, in this case $\frac{1}{4}$ inch. Repeat for each new position of

the generating circle (*stepping* with the dividers the distance around the circle that it has rolled along the base line), until a complete revolution has been made, then trace the curve through the points thus found.

The epicycloid and hypocycloid are generated in the same manner, the base circle replacing the base line.

Involute. — The involute is the curve generated

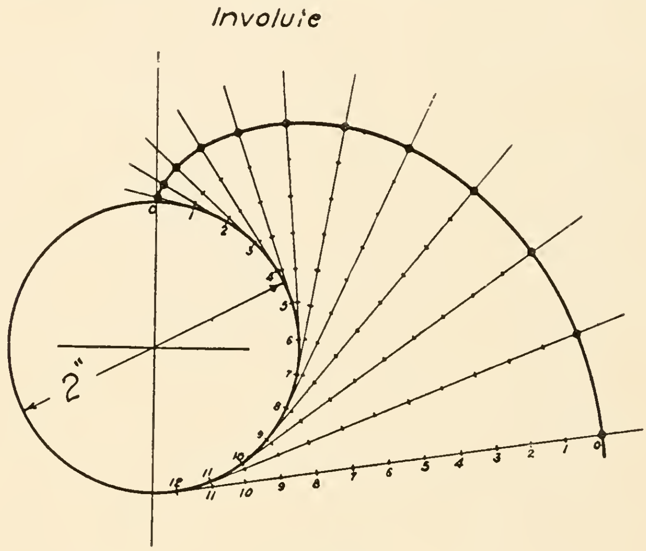


Fig. 40

by every point on a cord as it is wrapped upon or unwound from a cylinder.

To develop the involute mechanically, unwind a little bit of the cord at a time, and step off upon the line the distance unwound. Set the dividers to $\frac{1}{4}$ inch and step off 10 or 12 divisions upon the base circle; from these points draw tangent lines to represent the cord in different positions when being unwound. Then, with the dividers, step off on these tangent lines the number of points away from zero which each line is placed. Connect the

outermost point on each line and we have the desired curve.

Helix. — The helix, or screw, is the curve which would be generated upon a cylinder revolved at a constant speed against a point, the point meanwhile moving along at a constant speed parallel with the axis of the cylinder.

To generate this curve mechanically, divide the circumference of the cylinder into any number of

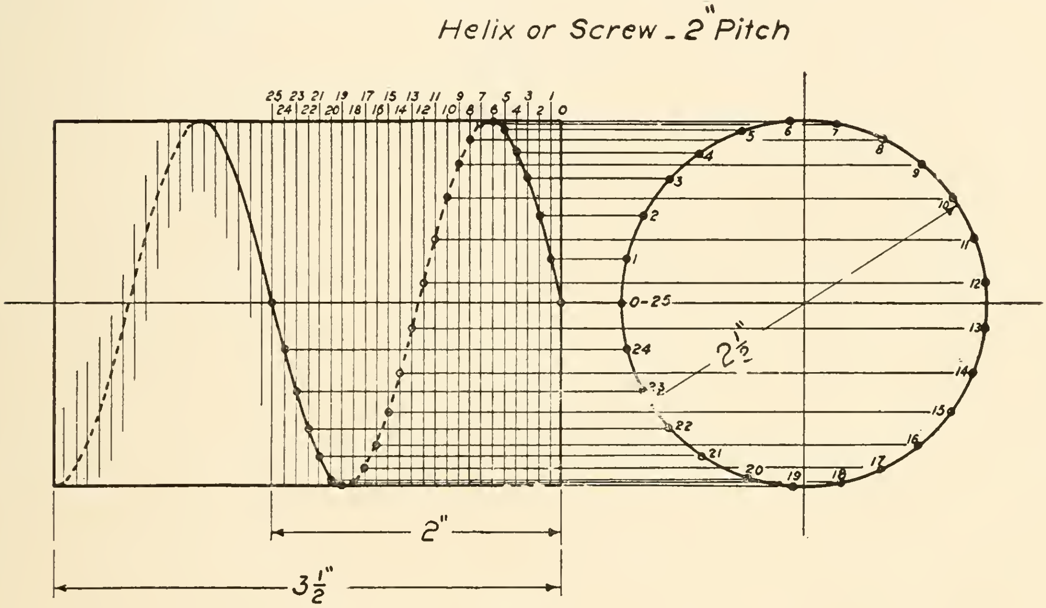


FIG. 41

equal parts, in this case 25, numbering these points from the left on the center line, as shown in Fig. 41. Divide the pitch distance on the cylinder into the same number of equal spaces (25) by which the circumference of the cylinder was divided. Now locate points on the side view of the cylinder, at the intersection of the vertical division lines with the horizontal projection lines from the points on the end view of the cylinder; then trace the curve through the points thus found.

CHAPTER VIII

CONIC SECTIONS — INTERSECTIONS AND DEVELOPMENTS

Conic Sections — Intersections. — A little study of the subject of conic sections and the intersections of surfaces should demonstrate the fact that orthographic projection is the basis for the solution of such problems as are here presented. Further study should bring out the fact that *points* and *lines* are the basic elements used to obtain this solution, for by their use curves and sections of circular figures may be projected in very simple fashion.

In general the subject matter of this chapter may be studied from three fairly distinct points of view. As subject matter in the study of descriptive geometry wherein these solids would serve as a basis for studying the theory of surfaces, portions of the subject matter may be considered simply as problems in orthographic projection, and, finally, the whole may serve as the basis for practical work in drafting patterns for sheet metal workers.

Our desire is to present this matter as a study in orthographic projection and the development of surfaces, to the end that the student may be better prepared to solve the various difficult drafting problems which the engineer is apt to encounter.

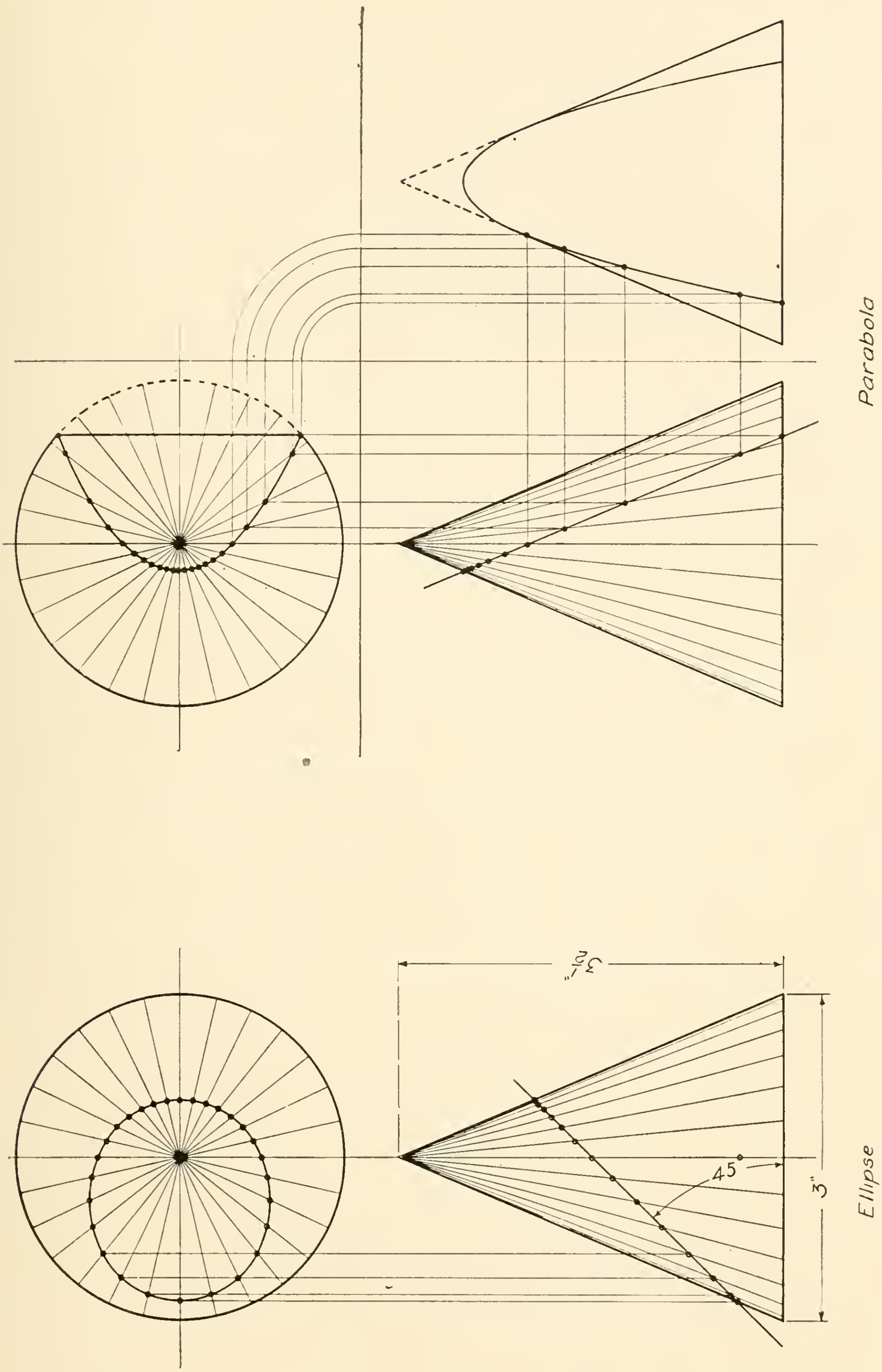


Fig. 42

The illustration in Fig. 42 shows a cone cut by a plane in two different ways. When a cone is cut by a plane which passes between the apex and the base at any angle (except a right angle) the section will be an ellipse. If the cone is cut by a plane which is parallel with one side, the section made is a parabola.

Problems. — Lay out the cones to the dimensions given. Divide the base circle of the top view into any number of points equally or unequally spaced; from these points draw lines to the apex; now project the lines down onto the side view. The student will find it a convenience to make the line spacing on the upper half of the top view a duplicate of that on the lower half.

To develop the ellipse, cut the cone as shown in the side view; the points made by the intersection of the cutting plane with the slope lines should then be projected to the *same lines* in the top view. By connecting these points we have a true ellipse.

In developing the parabola, place the cutting plane through the side view as indicated, and project the points of intersection to the top view in the same manner as for the ellipse. With the top and side views complete, it is quite a simple matter to develop the front view, point by point, as shown in the illustration.

Intersection of Cylinders. — The illustration, Fig. 43, shows two intersecting hollow cylinders and the developments of their surfaces.

To construct the curve of intersection of the two cylinders, divide the end view of the small cylinder

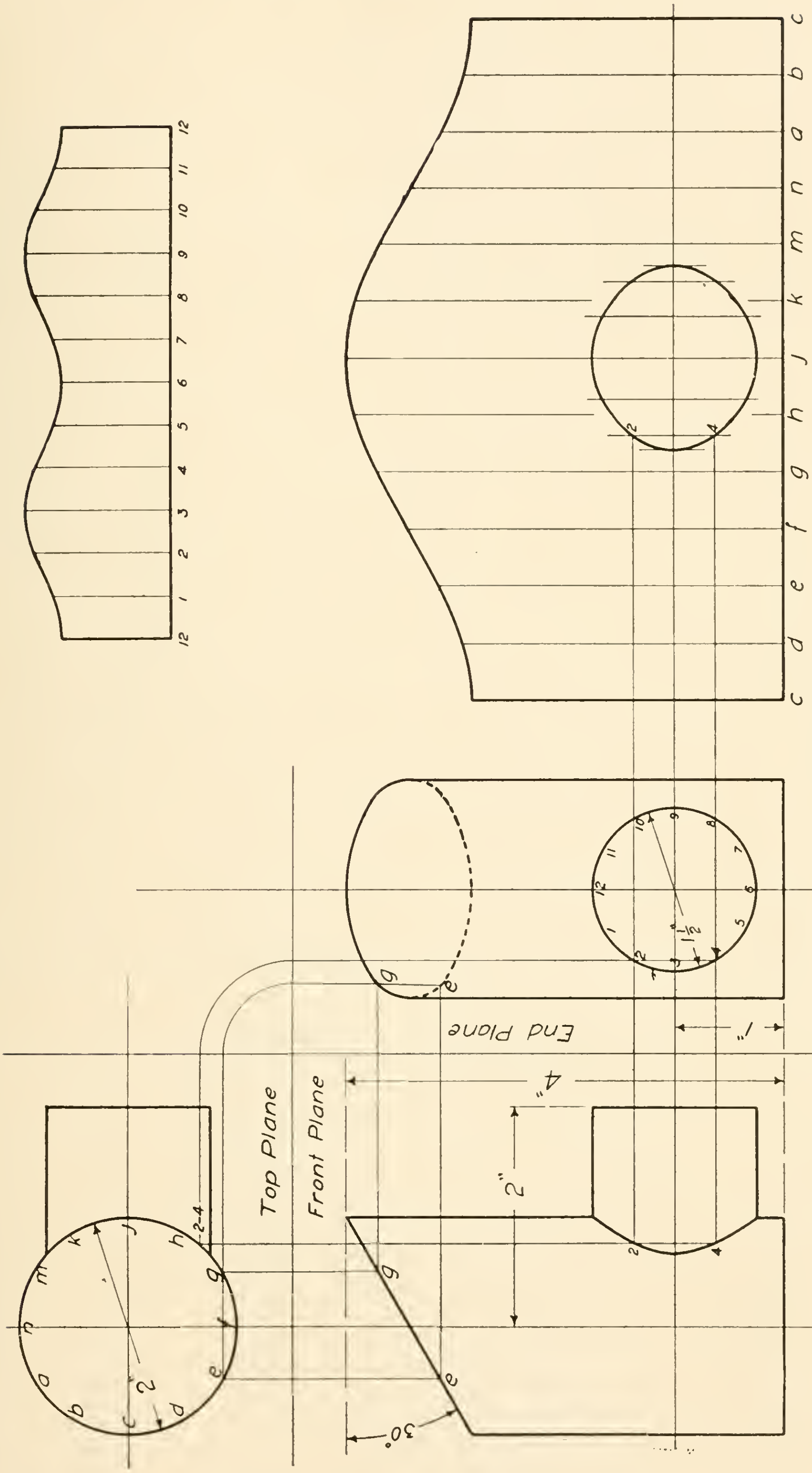


Fig. 43

into any number of points (for convenience an even number in this case), then project these points onto the other views. The curve is found point by point as indicated by points 2 and 4 on the illustration. The ellipse shown on the end plane is formed by cutting the large cylinder off at an angle of 30° with the horizontal plane; it is constructed in the same manner as the curve of intersection.

Development of Surfaces. — In most forms of sheet metal construction it is customary to prepare a pattern or templet on a flat surface, this pattern being of such outline that when it is formed or folded into its final shape it will form a part, or, in some simple patterns, the whole of the object for which the pattern was developed.

In commercial plants the drafting of these patterns is done with a high degree of accuracy, with the proper allowance for seams, and where the sheet stock is thick, as for boilers and tanks, allowance must also be made for thickness of plate, riveted joints, etc.

The different methods of developing a surface are usually described by the types of lines used for this purpose. As an instance, in our present problem we use parallel lines to develop the surfaces of the cylinders, hence the term "Parallel Line Development."

To construct the cylinder development, project the division points from the end view to the side view parallel with the cylinder axis. Find the circumference of the cylinder (by calculation, *not* by stepping it off with the dividers), lay off a base line

representing this length, upon which place the division points correctly spaced; from these division points erect parallel lines or coördinates. The length of these lines may be found by projection from the side view or these lengths may be transferred with a compass.

Intersection of Cone and Cylinder. — The illustration, Fig. 44, shows a cylinder intersecting a cone; the curve of intersection is found in much the same manner as that of the intersecting cylinders, but with this vital difference that it is *first* necessary to project the radial lines from the view on the end plane to the top view, so as to have an element upon which to project the points.

A simple method of construction is to draw in these radial lines from the apex to the base of the cone *through* the *end view* of the cylinder, let the first line be tangent to the cylinder and the other lines be located by eye as shown. The points formed by the intersection of these radial lines with the end of the cylinder may be used to produce the curve as indicated by points 1 and 4.

Radial Line Development. — The second method of development is derived from the shape of the figure, the surface of the cone necessitating that radial lines be used in its development, from which we get the term "Radial Line Development."

When laying out the development of the cone, the student should bear in mind that the true length of the lines on the cone can be found on the "slant height" or the sides of the cone only, as in all other positions the lines are foreshortened.

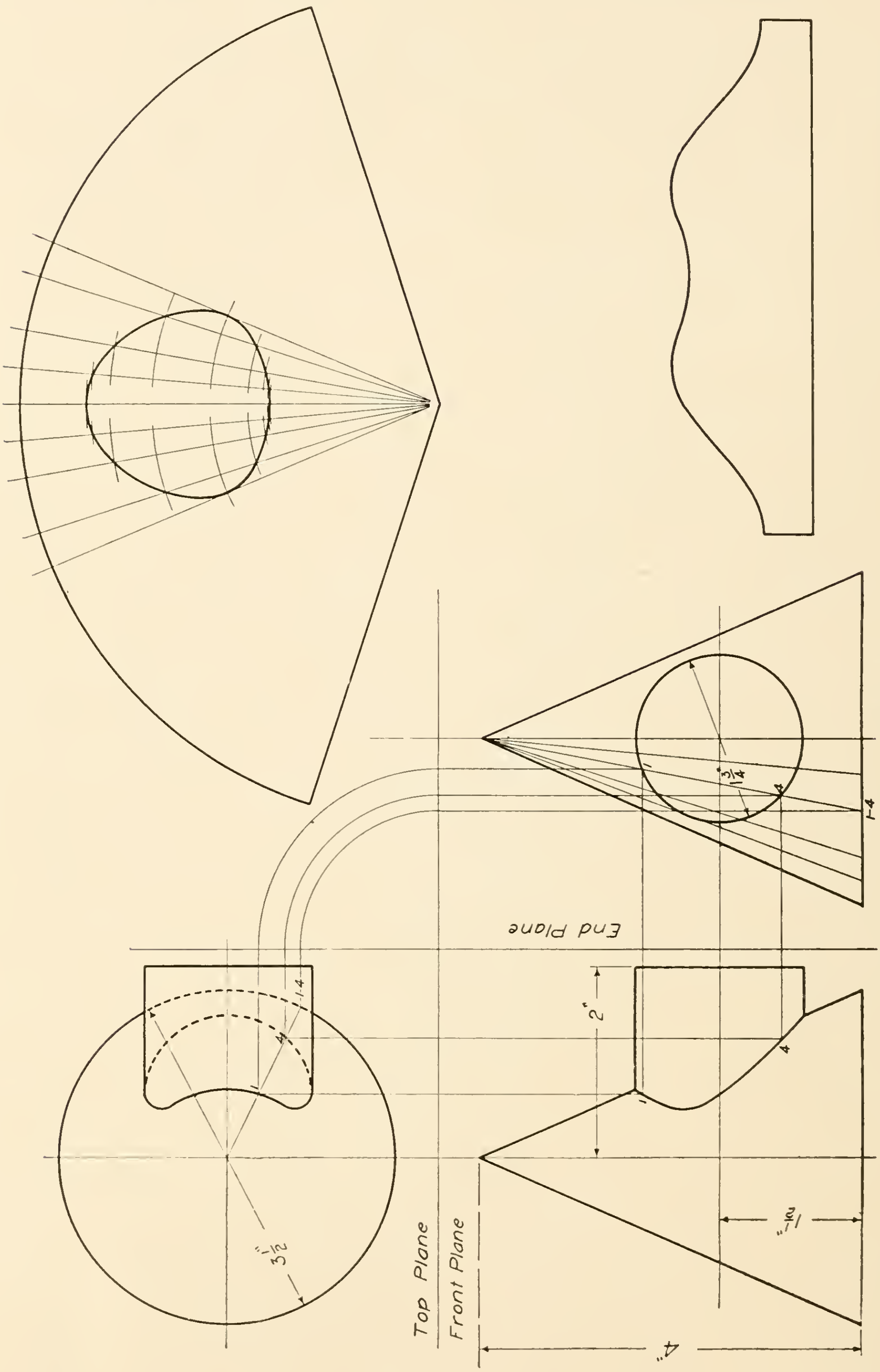

Top Plane
Front Plane
End Plane
2"
4"
$3\frac{1}{2}$"
$1\frac{3}{4}$"
$\frac{1}{2}$"
1-4
1
4

FIG. 44

Thus to get the true distance from the apex of the cone to point 1, this point must be projected to one of the sides. The student should also remember to use the *same* radial lines for the development that were used in finding the curve of intersection.

Triangulation Development. — One of the commonest methods of development derives its name from the fact that the surfaces of certain forms of construction may be divided up into a series of triangles.

To construct the development of the transition piece shown in the illustration, Fig. 45, first lay out the top and side views, dividing up the surface into triangles and marking the lines with letters and figures as shown. Then find the true length of each line by the method indicated in the illustration. Now, using these lines with the top and base lines, construct the triangles into which the figure had been previously divided. Connect these triangles in the manner indicated by the partial development shown in Fig. 45, and the result will be the complete pattern desired.

Problems. — Make developments of the cone surfaces remaining below the cutting planes in Fig. 42.

Lay out a hexagonal pyramid which is 3 inches in diameter across flats at the base and $4\frac{1}{2}$ inches high. Cut this pyramid $1\frac{1}{2}$ inches below apex by a 45° plane. Make a development of surface of pyramid below plane.

Make an intersection drawing and the development of two cylinders. The large cylinder is $2\frac{1}{4}$ inches in diameter by 4 inches long. The small cylinder is $1\frac{1}{2}$ inches in diameter by 1 inch long on

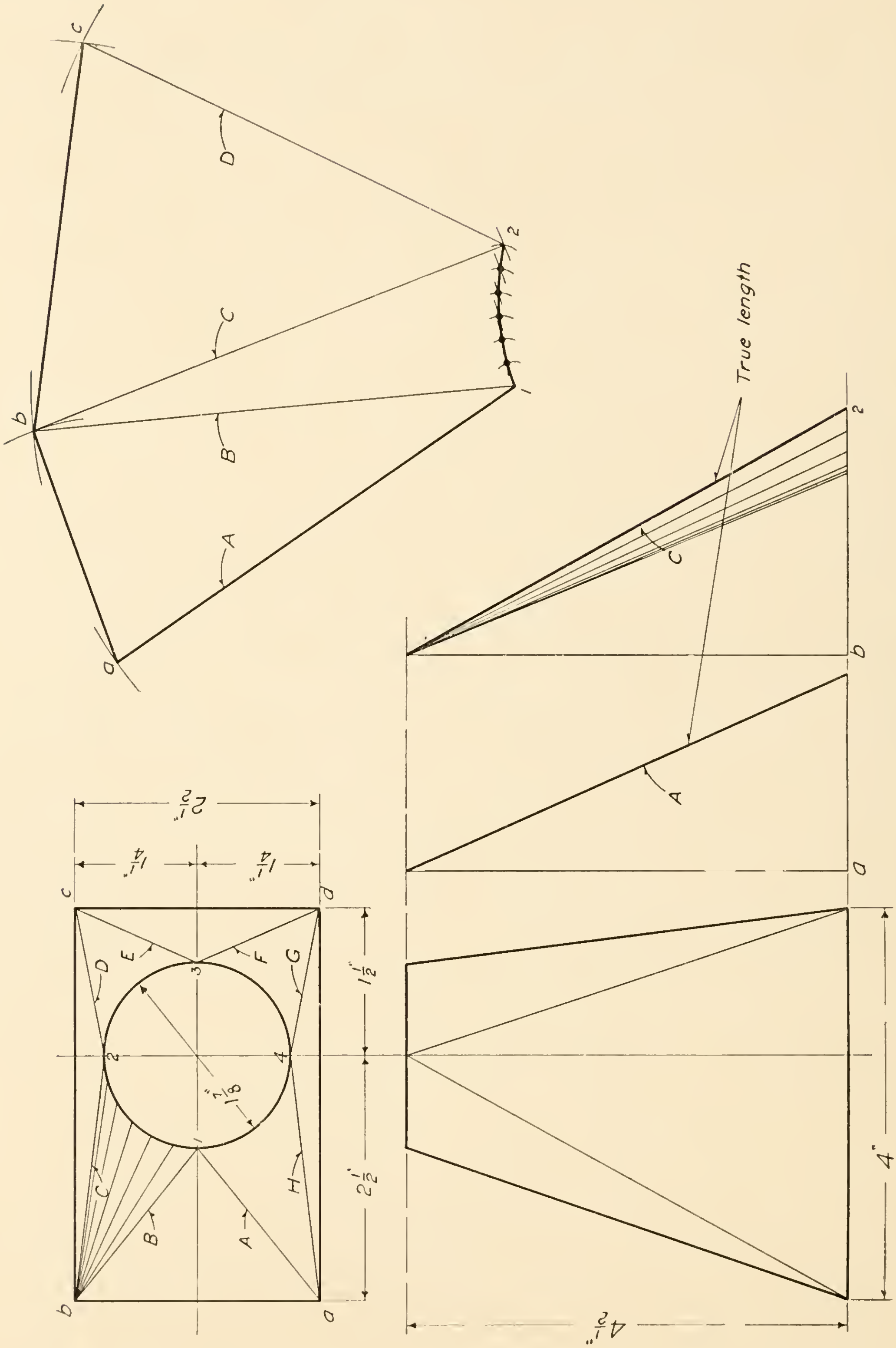

True length
$2\frac{1}{2}''$
$1\frac{1}{4}''$
$1\frac{1}{4}''$
$1\frac{1}{2}''$
$2\frac{1}{2}''$
$1\frac{1}{8}''$
$4''$
$4\frac{1}{2}''$

Fig. 45

short side; axis of small cylinder lifted to an angle of 45° intersects circumference of large cylinder 2 inches above the base.

This problem is an excellent illustration of the use made of auxiliary planes.

CHAPTER IX

ISOMETRIC AND OBLIQUE DRAWING

Isometric Projection. — It is frequently necessary for the mechanical draftsman to make one-plane projection drawings of certain forms of construction. If these illustrations are prepared as they would appear from a single view-point they are termed perspective drawings.

Perspective drawings best illustrate this type of work from the fact that they represent the object as it would appear to the eye; at the same time there are certain disadvantages connected with this system. The main objection is that these drawings cannot be laid out from dimensions as mechanical drawings are, and this one disadvantage is quite serious from the point of view of the draftsman.

Isometric, or *equal measure* projection, is a fairly satisfactory substitute for perspective drawing for certain classes of work.

This method may be termed approximate perspective, as it represents an object in such fashion that it looks approximately as it would appear to the eye. The primary difference between two drawings of an object, one in perspective and the other in isometric, is that in the perspective drawing the surface lines converge at a certain distance from the object, as shown in Fig. 46, while in the isometric drawing these same surface lines are parallel.

For certain shapes, or at least for some views, isometric drawings are not satisfactory, as the figure appears badly distorted and unpleasing to the eye,

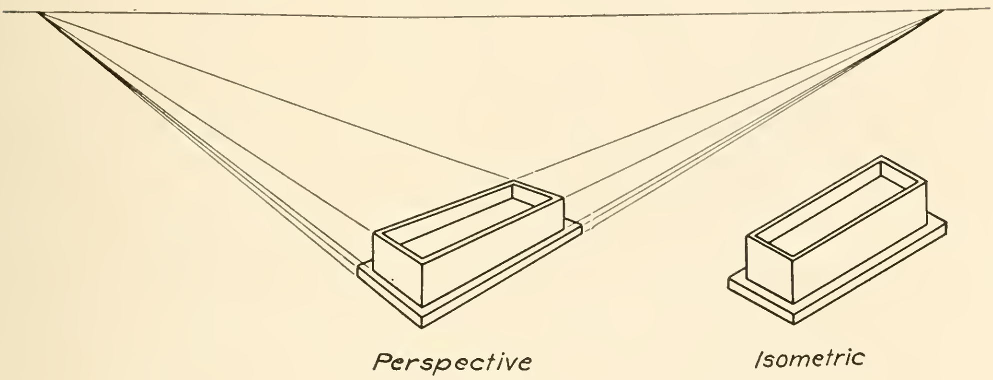


Fig. 46

but for most subjects it will be found quite satisfactory.

Isometric projection is based on the theory that

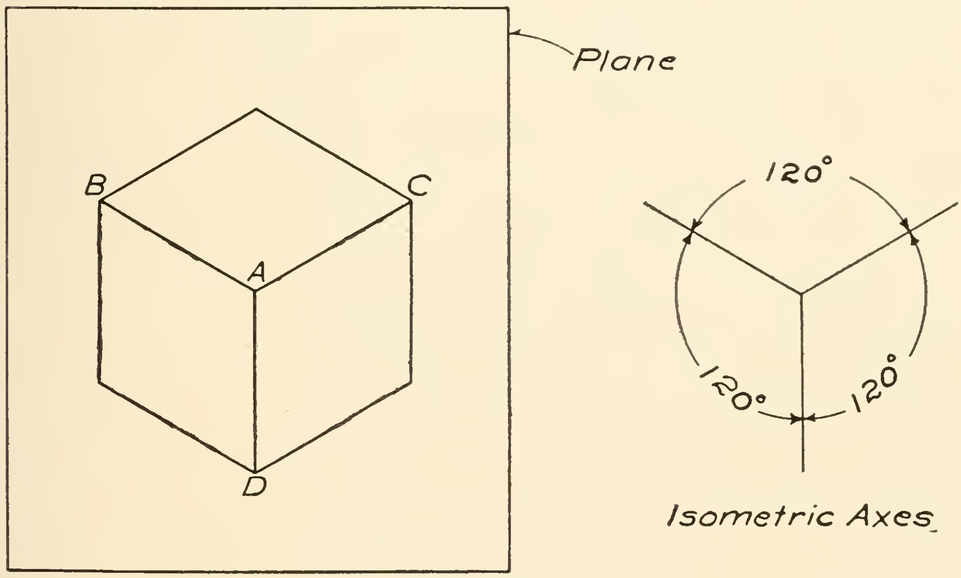


Fig. 47

the object is viewed through a plane with which certain main features of the body are equally foreshortened. To illustrate, the cube shown in Fig. 47 is tilted forward until the edges AB, AC and

AD are equally foreshortened as seen through the plane.

This figure also illustrates what are known as the isometric axes and their origin, as these three edges of the cube (AB, AC and AD) considered as lines,

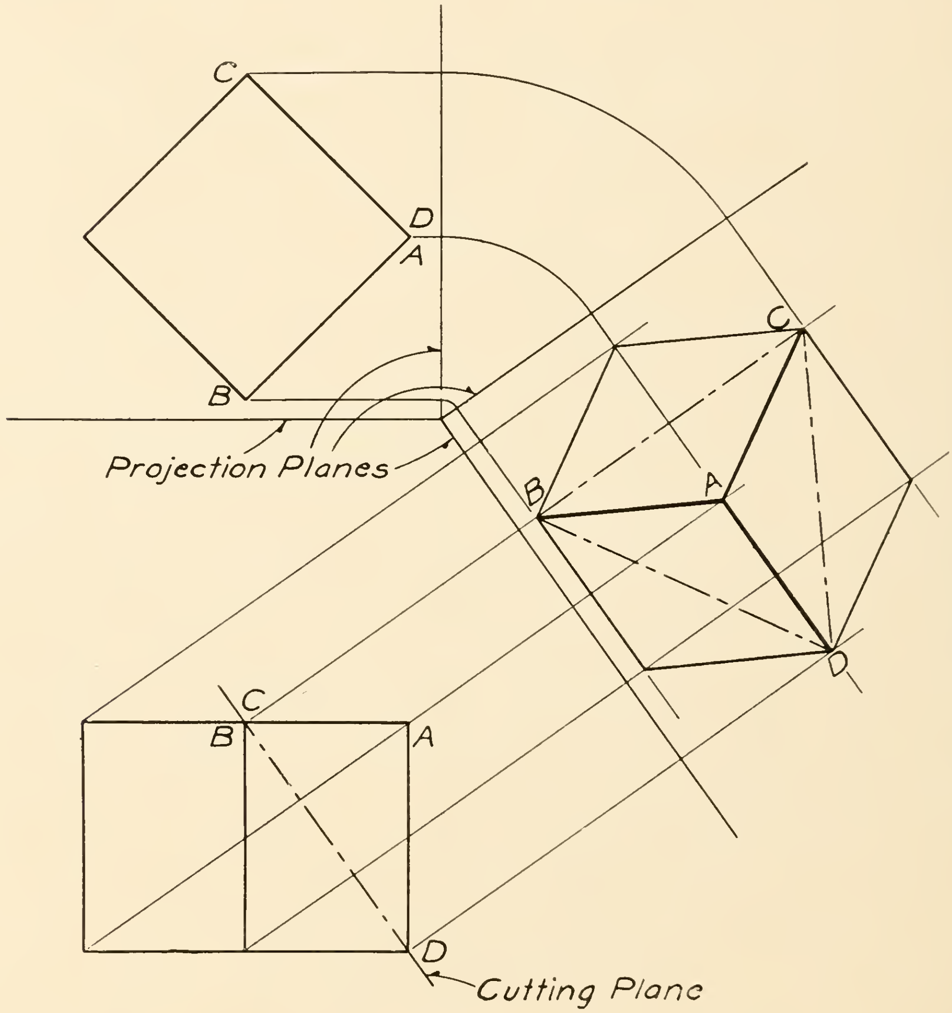


FIG. 48

are separated by an equal angular space and correspond to the three dimensions, length, breadth and height.

Figure 48 represents a two-view mechanical drawing of a cube, from which is projected (orthograph-

ically) an isometric view of the cube. This illustration shows the transformation from mechanical to isometric, the relationship between these two methods, and makes clear the sound basis from which isometric projection was derived.

To demonstrate the theory that the surfaces of the body are equally foreshortened, we place the cutting plane through points *B*, *C* and *D* of the cube; then as the projection plane is located parallel with the cutting plane, the portion of the cube cut away (as indicated by the dash lines in the isometric view) forms a triangular pyramid with corners of equal length.

The student should try to remember the following fundamental principles of isometric projection:

There are three basic lines known as isometric axes.

Isometric axes are separated by an equal angular space, and correspond to the dimensions, length, breadth and height.

Vertical lines on the object are vertical lines on the drawing. Lines parallel on the object are parallel on the drawing. Right angles on the object are either 60° or 120° on the drawing;

Lines not parallel to one of the isometric axes are termed non-isometric lines. Measurements may be made *only* on isometric lines.

Isometric Drawing. — When a drawing has been made according to the rules of isometric *projection,* the isometric lines forming this drawing are eighty-one hundredths (0.81) of their true length. As this necessitates using an isometric scale, it is generally

considered good practice to use an ordinary scale to lay out the figure to the dimensions given. The result will be an isometric *drawing,* not a projection, but as the only difference is in the *size* of the figure, this is of little importance.

Coördinate Axes. — When laying out isometric drawings of certain shapes, a very convenient aid

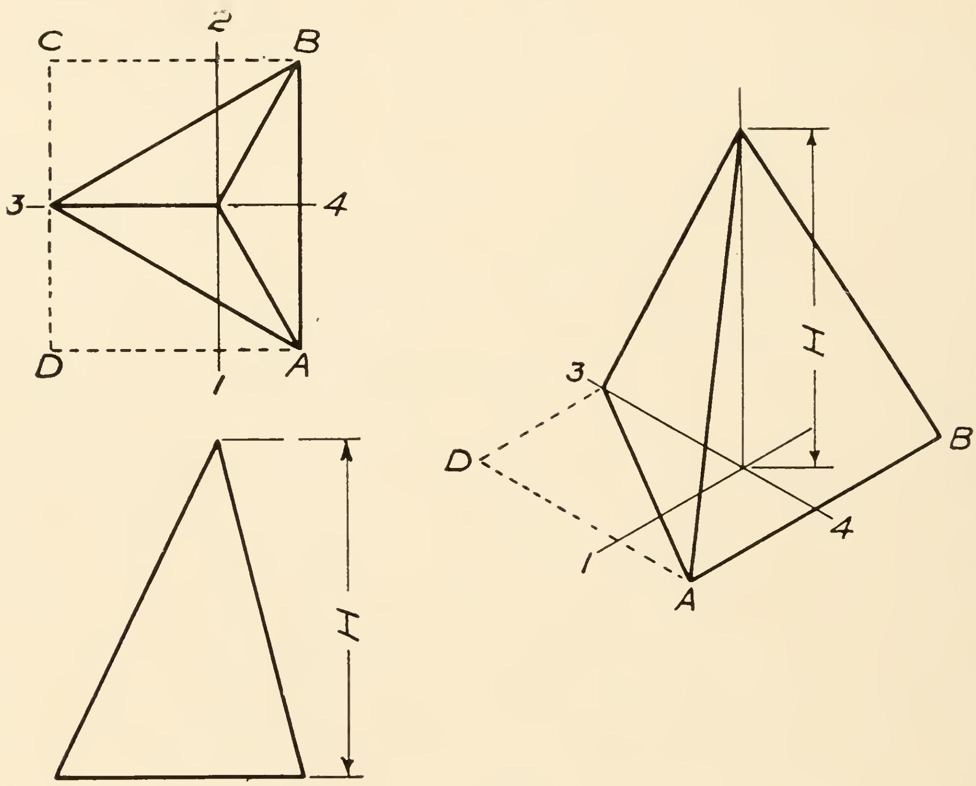


Fig. 49

is the related axes, usually termed coördinate axes. Figure 49 illustrates this feature as it shows how the isometric view of a triangular pyramid may be constructed with the aid of these axes and the mechanical views.

To construct Fig. 49, lay out the mechanical views as shown, then draw a rectangular figure about the top view (as indicated by $ABCD$). This gives a

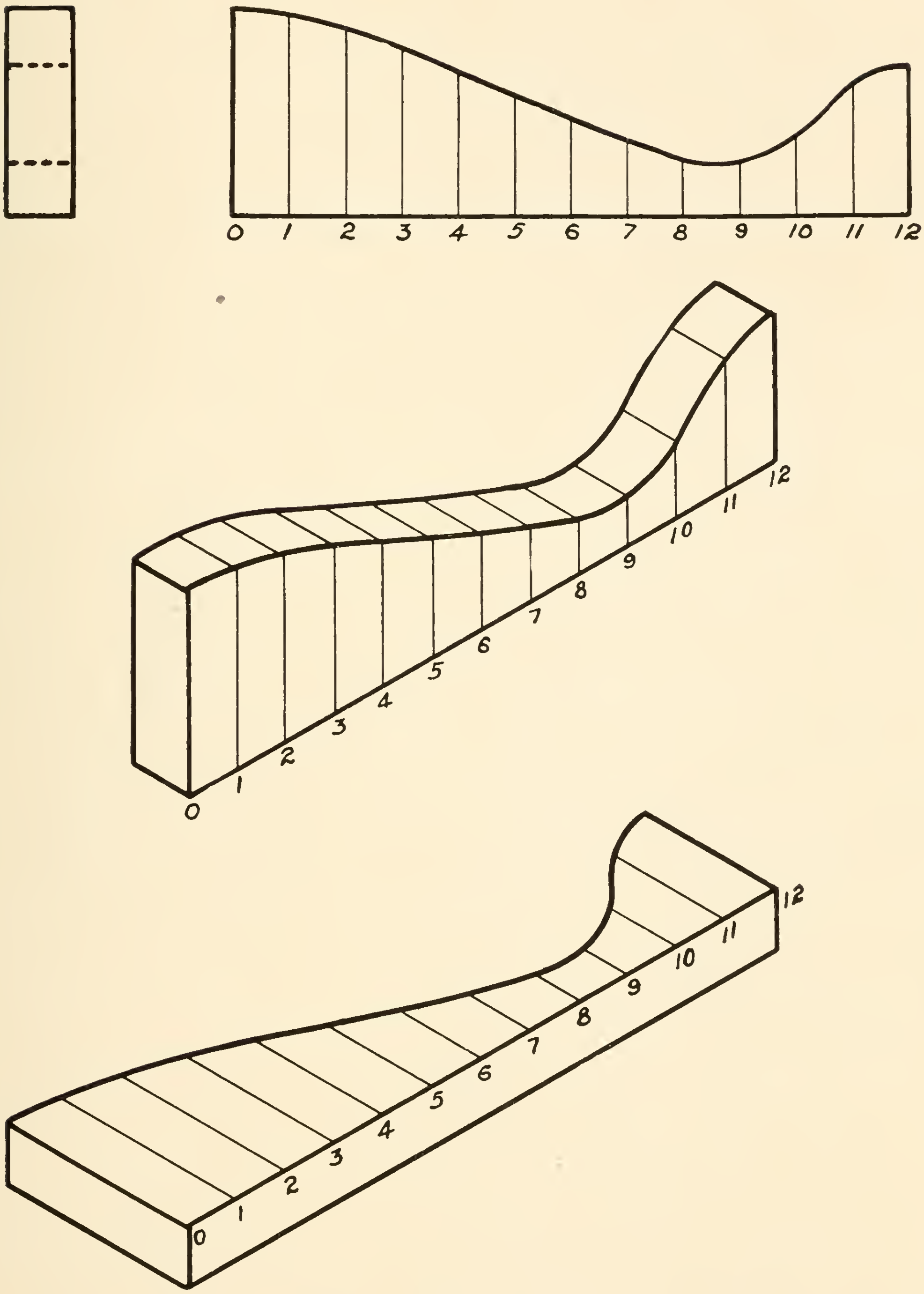


Fig. 50

figure that parallels the isometric axes and on which we may locate the base of the pyramid. After this has been done, find the point of intersection of the

axes (1–2 and 3–4) on this figure, and from this point erect a perpendicular on which lay off the height of the pyramid. Now then connect the apex point with the corners on the base and the figure is complete.

To emphasize the convenience of these related axes, the student is reminded that measurements may be made only on isometric lines, and as the lines forming the outline of the pyramid base are not

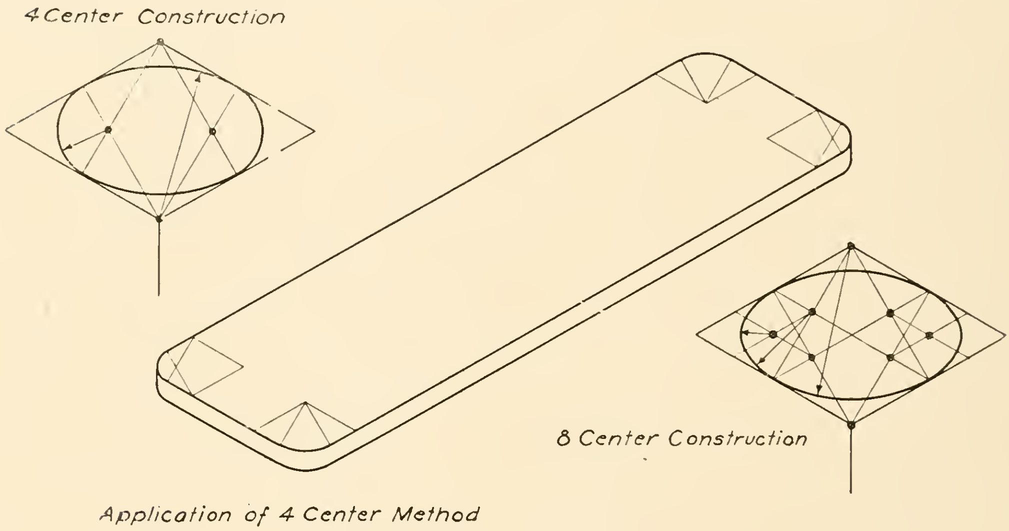


FIG. 51

at right angles with each other, only one side may be placed on an isometric axis.

Figure 50 shows the application of the coördinate axes to quite a differently shaped figure from our last illustration. The mechanical view of the side of the piece is divided into a certain number of parts (any number), spaced either evenly or unevenly; then these lines or axes are used as shown when constructing the isometric view. Two applications are shown, one of which is pleasing to the eye and the other quite the reverse.

Isometric Circles. — The methods of constructing isometric circles should require little explanation and their application to rounded corners should be readily understood from the illustration, Fig. 51.

For general purposes the four-center method will be found satisfactory and, with a little study of the

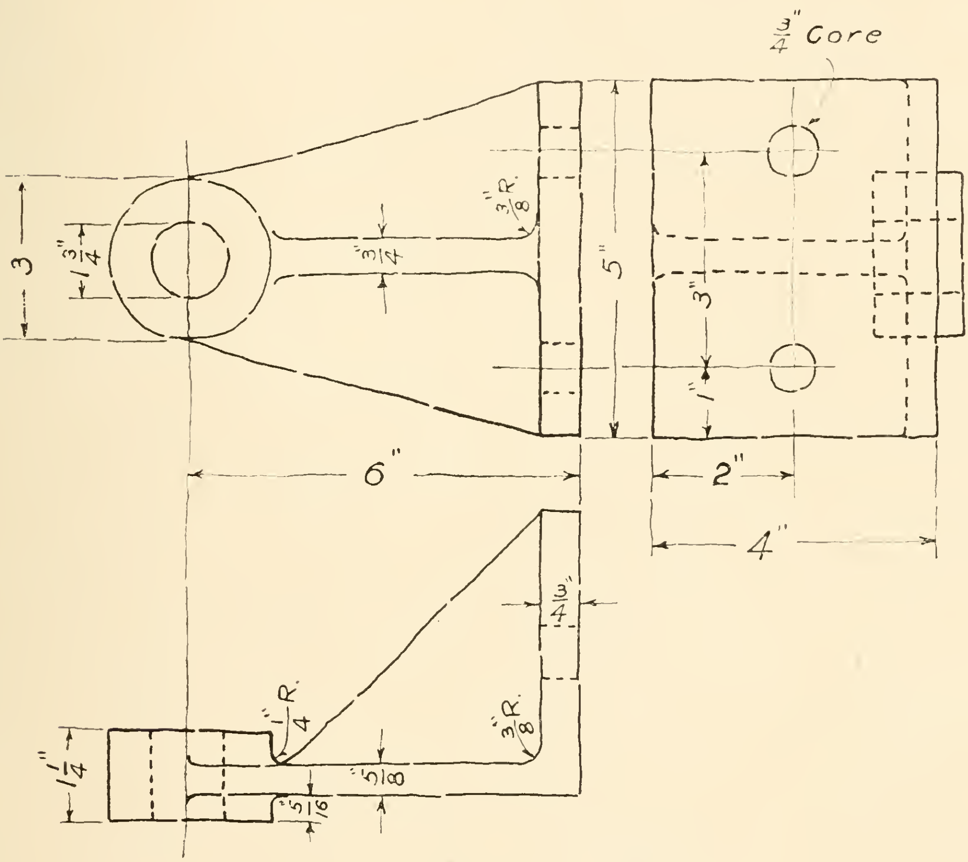


Fig. 52

illustration, the student should be able to apply this method to his work.

One feature which it is well for the student to bear in mind is that to construct any circle arc, he should lay out an isometric square of the *circle diameter* as a means of locating the position of the radius center.

Problems. — Make an isometric drawing of a hexagonal pyramid. Size of pyramid 3 inches in diameter *across flats* at base by $4\frac{1}{2}$ inches high.

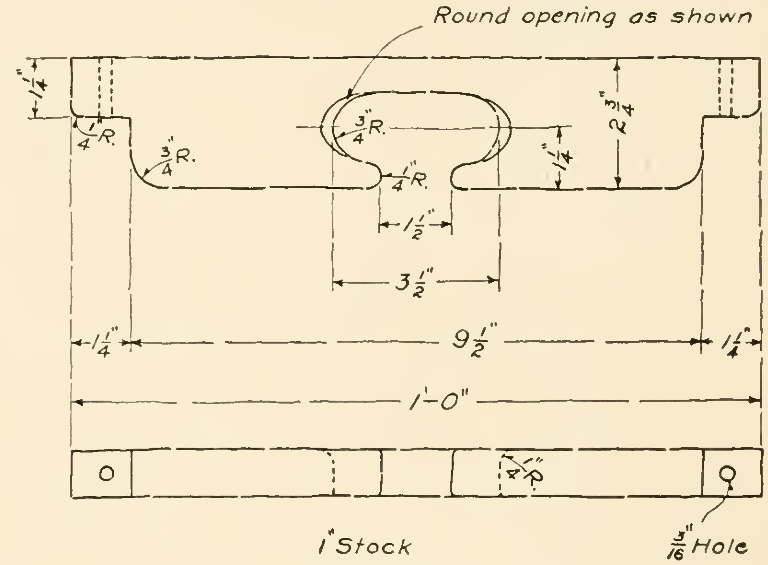


Fig. 53

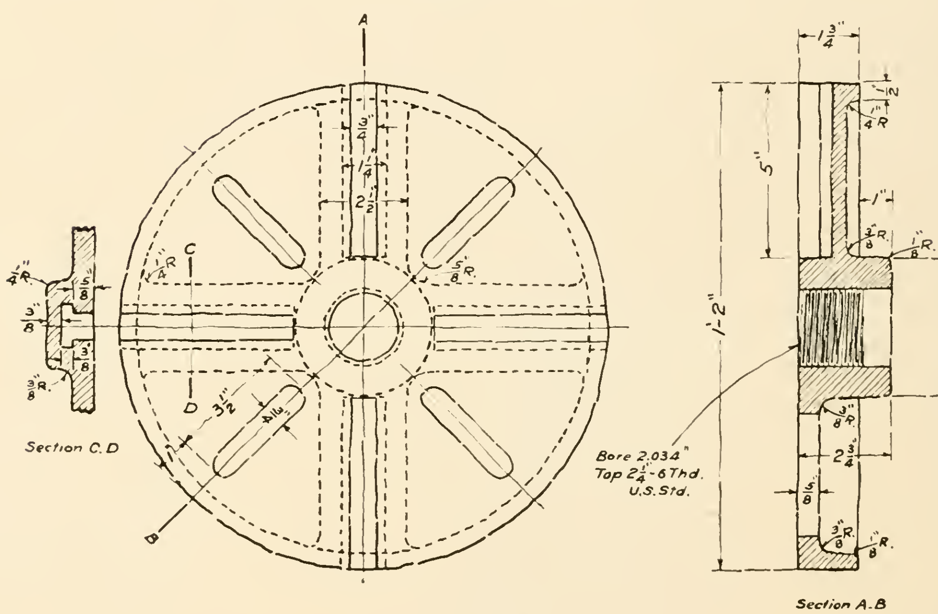
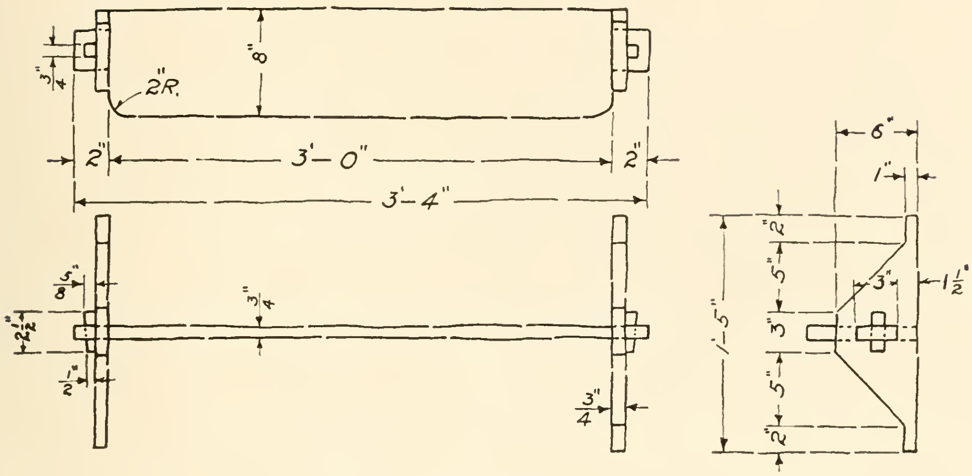


Fig. 54

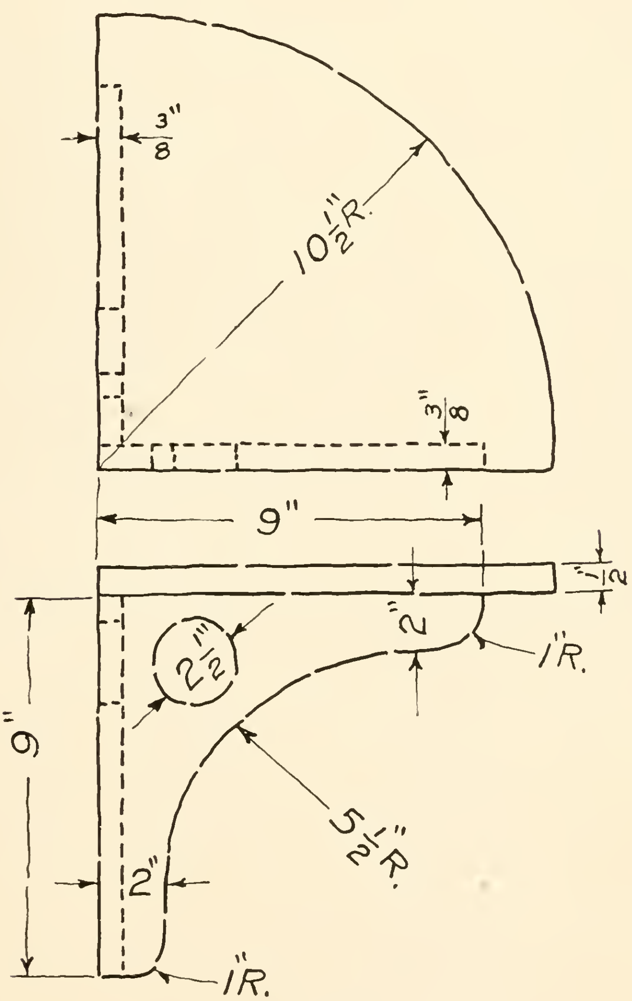
Make an isometric drawing from the bracket sketch in Fig. 52.

Make an isometric drawing from the broom holder sketch in Fig. 53.



3/4"
2"R.
8"
2"
3'–0"
2"
3'–4"
3/4"
3/4"
6"
1"
2"
5"
3"
3"
5"
2"
1'–5"
1 1/2"

Fig. 55



3/8"
10 1/2"R.
3/8"
9"
1/2"
2"
1"R.
2 1/2"
9"
5 1/2"R.
2"
1"R.

Fig. 56

Make two isometric drawings, one showing the back and the other the face, from the lathe face plate sketch in Fig. 54.

Make an isometric drawing from the shelf sketch in Fig. 55. Owing to the length of this object it

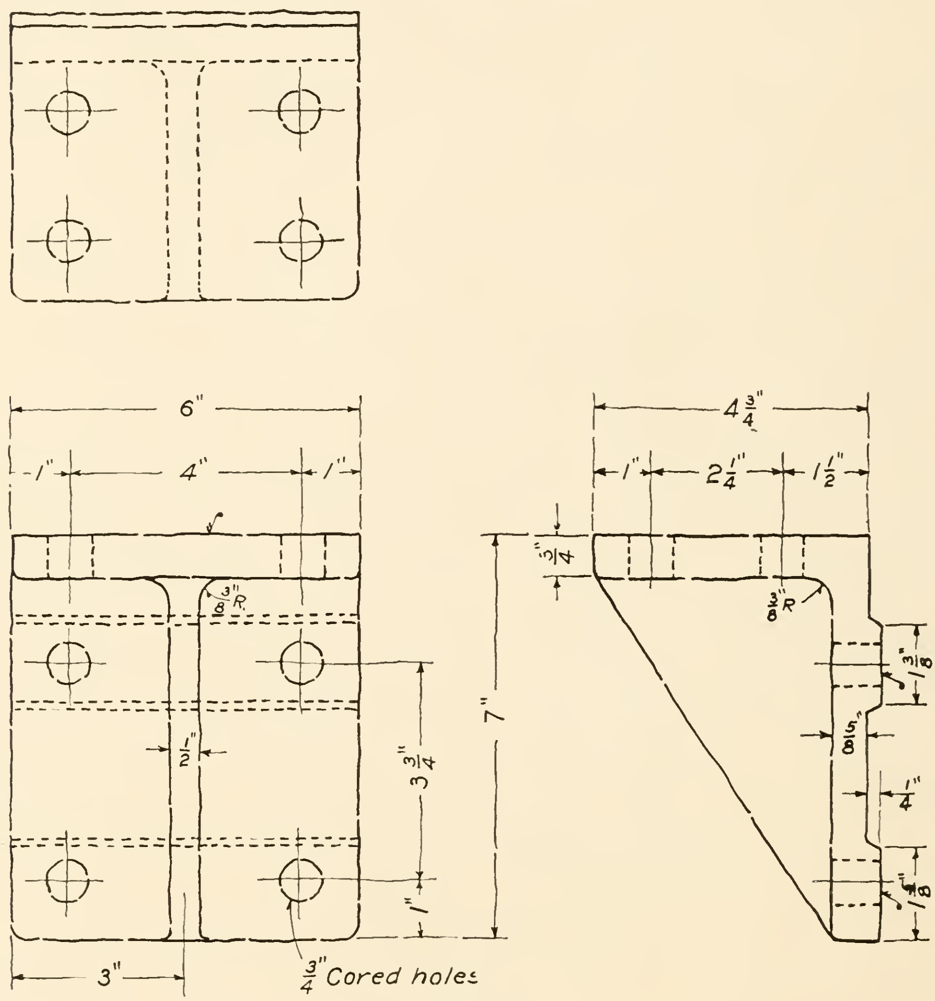


Fig. 57

will be found necessary to "break" the shelf or to draw it to a scale of less than full size so that we may use one of the standard sheets of drawing paper.

Make an isometric drawing of the corner shelf shown in Fig. 56. This drawing to represent the axes reversed; that is, the view is taken from *below*

and directly in front of the center of the shelf, as if the shelf were tilted backward.

Make an isometric drawing of the bracket shown in Fig. 57. This drawing also to represent the reverse axes.

Oblique Drawing. — As isometric projection is an approximation of angular perspective, so oblique projection may be compared as an approximation of parallel or one point perspective.

The basis of oblique projection is to place one surface of an object parallel with the picture plane as in orthographic projection, this surface being drawn to its true dimensions. Surfaces of this object, which are normally at right angles with the front surface, may be shown at any angle with this face. The angles which are in most common use are 45° and 30°, due, in a large measure, to the convenience of having triangles of these angles.

Figure 58 shows an oblique drawing of a cube, the corners *A–B*, *A–C* and *A–D* representing the axes. Measurements may be made on lines parallel to these axes; circles are constructed as in isometric, though the radii centers may fall outside of the construction square under certain conditions. In general the method of drawing is quite similar to isometric, but with this difference, the isometric system may be projected direct from orthographic views, while the basis of the oblique system is arbitrarily assumed.

Cabinet drawing is similar to oblique drawing with the exception that lines parallel to the cross axis *A–C*, in Fig. 58, are made one-half their true length in an

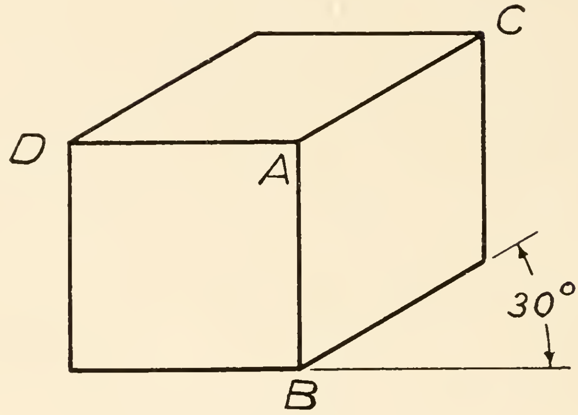


Fig. 58

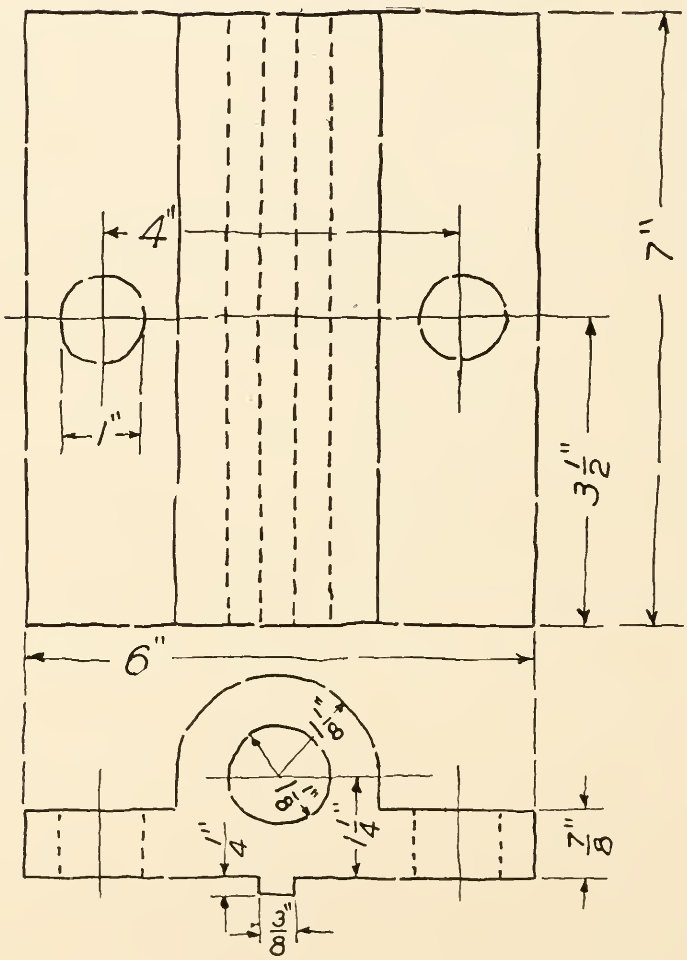


Fig. 59

attempt to approximate the foreshortening effect of perspective.

Problem. — At Fig. 59 is shown a two-view orthographic sketch of an object from which the student is expected to make an oblique drawing, bearing in mind that there is less liability of a distorted view if the irregular face of an object is placed parallel with the picture plane.

CHAPTER X

DRAFTING ROOM CONVENTIONS

Drafting Room Conventions. — The engineering student should have a fair working knowledge of certain customs or practices which are in general use in commercial drafting rooms. These conventional

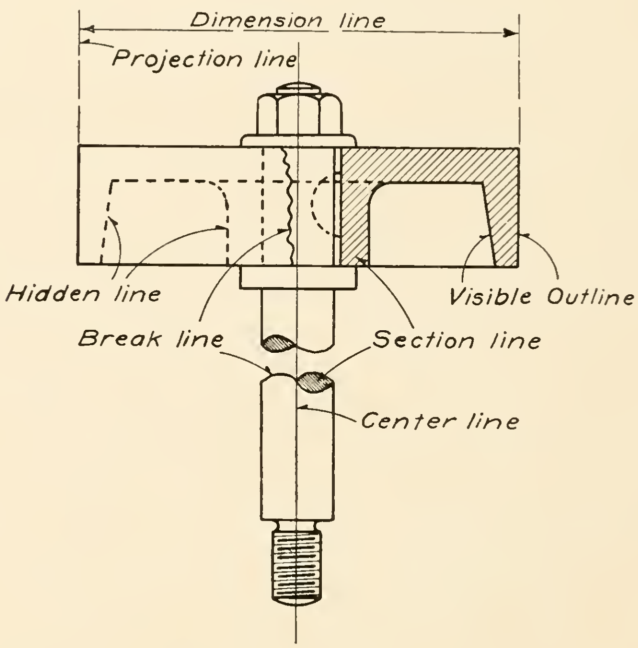


Fig. 60

methods vary with different firms, but it is comparatively easy to learn these variations if one is familiar with the customs which are generally known to the engineering profession.

Lines. — There is a reasonable degree of uniformity among commercial drafting rooms in regard to the

use of certain types of lines to indicate surfaces and to convey certain ideas. With some variations the lines shown in Fig. 60 are in common use for the purpose indicated clearly in the illustration.

Screw Threads. — Figure 61 illustrates a number of screw-thread cross sections; this illustration is intended to give the student an idea of the proportions of these different types of threads, each of which is well suited for some particular purpose in engineering work.

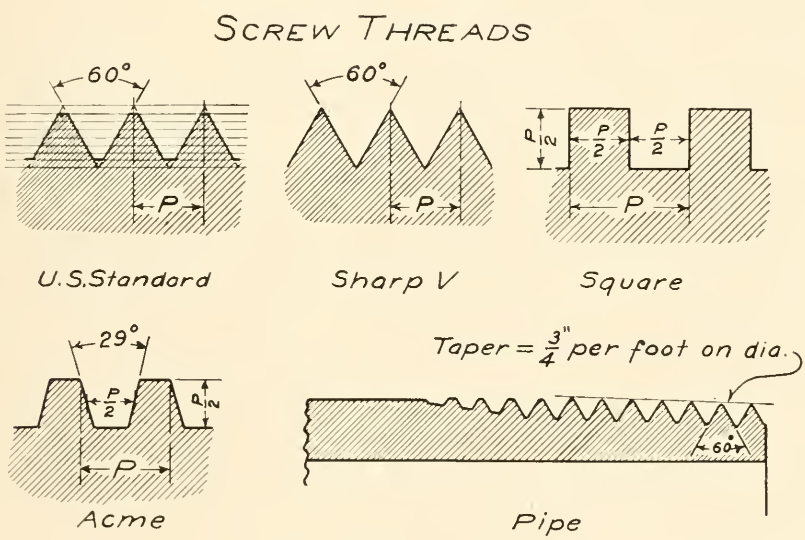


FIG. 61

Generally speaking, we do not show *true* representations of screw threads on working drawings, there are at least two good reasons for this: one is the excessive cost, and the other, that it is unnecessary. Instead of taking the time required to draw in threads as they really appear, the draftsman uses one of the conventional methods to indicate a threaded surface. As a rule, the purpose of indicating screw threads on mechanical drawings is to inform the shop-man where, how far, and what pitch threads

are to be cut on certain portions of an object. Usually this information is furnished by indicating the part to be threaded by one of the conventional methods, and by means of dimensions and notes giving the specific information necessary.

Figure 62 illustrates what is possibly one of the most simple conventional methods of indicating screw threads under different conditions. When indicating thread by this method it is not essential

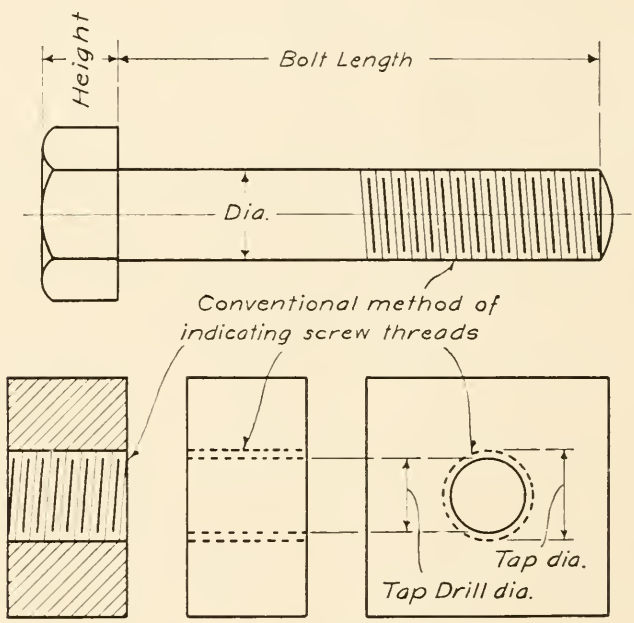


Fig. 62

that the space between the light lines be just the same as the pitch of the thread, or that the lines be sloped at exactly the correct angle, but it is of importance that the threaded surface as a whole look approximately correct; that is, wide spaces for coarse pitch and narrow spaces for fine pitch, etc.

Where the slope is correct for a single-thread screw, a line drawn at right angles to the center line of the screw should touch the end of one of the light

lines at one side and pass midway between that line and the next on the opposite side. In other words, the slope equals half of the pitch of the thread.

Fasteners. — When assembling the various forms of engineering construction it is necessary to make use of a great variety of fastening devices, these various fasteners being designed to suit varying purposes and needs. Figure 63 illustrates a group of fasteners which are in common use for *holding*

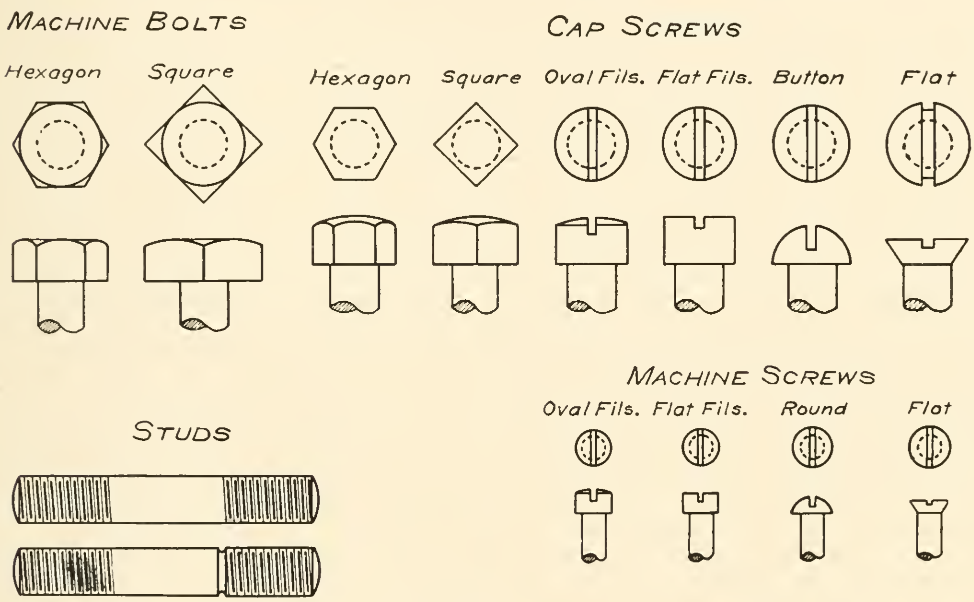


FIG. 63

parts together; these devices are used either alone or in conjunction with some of the nuts shown in Fig. 64.

These latter also vary to suit the particular purpose for which they are needed.

The illustration in Fig. 65 shows a group of fasteners, each of which is in common use as a device for locking *two revolving* parts together so that they shall move as one. The fasteners shown are merely

a few of the most common types and each is especially adapted for some particular purpose.

The set screws shown in Fig. 66 are used for a purpose quite similar to that for which keys are

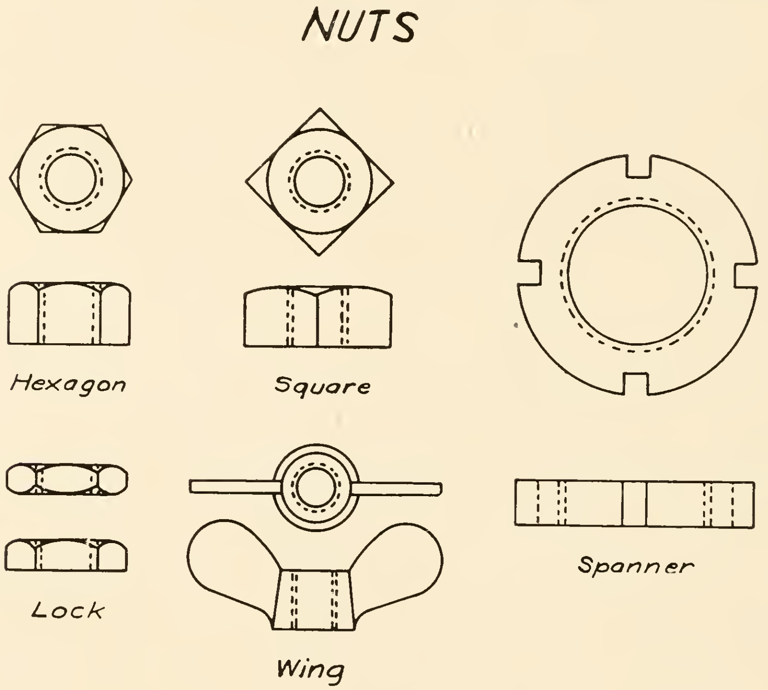


Fig. 64

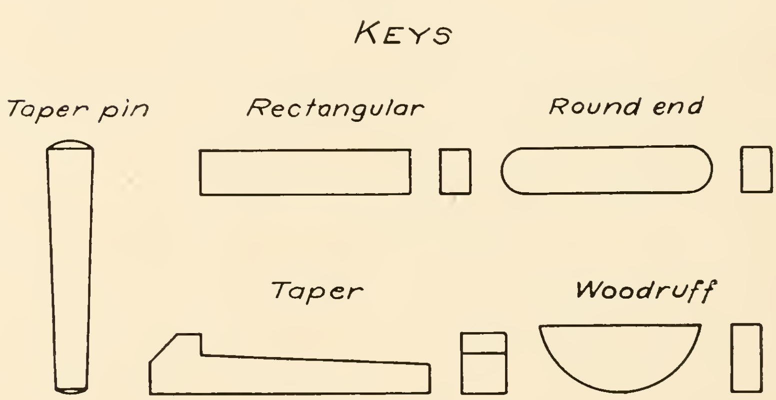


Fig. 65

needed: that is, to lock two parts together so that their relative positions are stationary. These parts may be revolving ones, or they may be sliding pieces which it is desirable to adjust from time to time.

The headless type of set screw is especially desirable for use with revolving parts as there is no projecting head to catch a workman's clothing which may come in contact with the revolving mechanism.

The rivet shown in Fig. 67 is a permanent fastener, as distinguished from all of the others previously illustrated, each of which may be removed without undue difficulty unless rusted seriously. The balance of the fasteners shown in Fig. 67 are

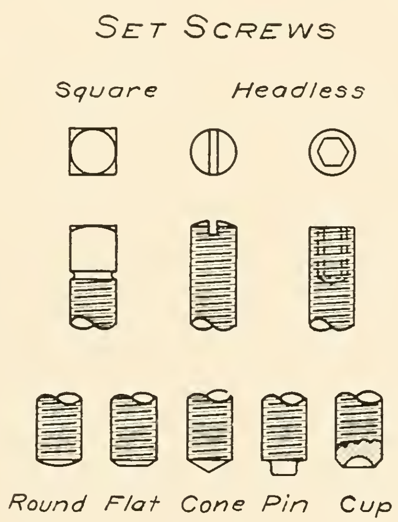


FIG. 66

of the adjustable type used very commonly in bridge construction.

Breaks. — It frequently happens, owing to the size and shape of an object, that it is necessary to "break" out a portion of this object, as illustrated in Fig. 68, so that we may be enabled to place it on a standard-size sheet of drawing paper. When making a "break" of this character, it is necessary that the portion taken out shall be of the same size and shape as the material left on each side of the broken edges, so that no misunderstanding as to the

true size and form of the object may be caused.

Sectioning. — One of the necessary conventions in constant use consists in showing views of objects with portions cut away, or "in section," as it is generally termed. The main advantage of this convention is that it enables us to more clearly repre-

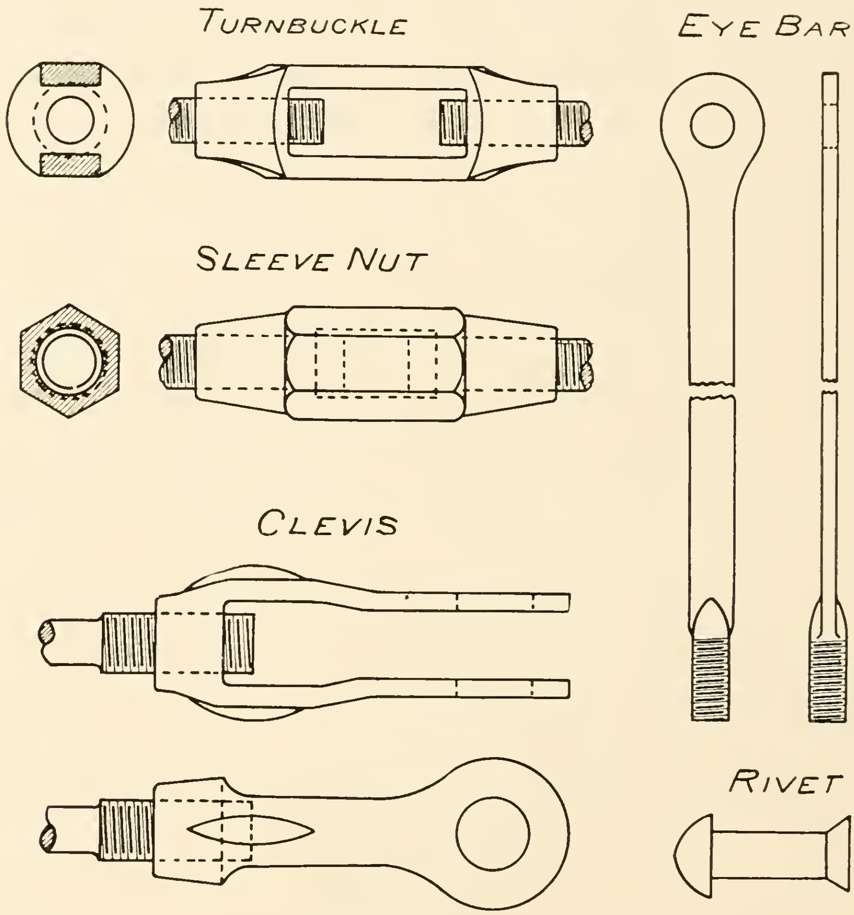


FIG. 67

sent the form of a piece and frequently dimensions may be placed in a more satisfactory manner on a sectional view.

As an aid in indicating that a piece is in section the surfaces touched by the cutting plane are covered with light lines called "section lines." These lines are drawn with the aid of a 45° triangle as a ruling

edge, the triangle being held against the **T** square and moved for each line. Where two or more pieces assembled together are shown in section, the different parts are shown more clearly by sloping the section lines in opposite directions where the parts join.

In the past it has been the custom to use section lines of differing character for different kinds of metals. The main purpose of this custom was to convey an idea of the material by this means and

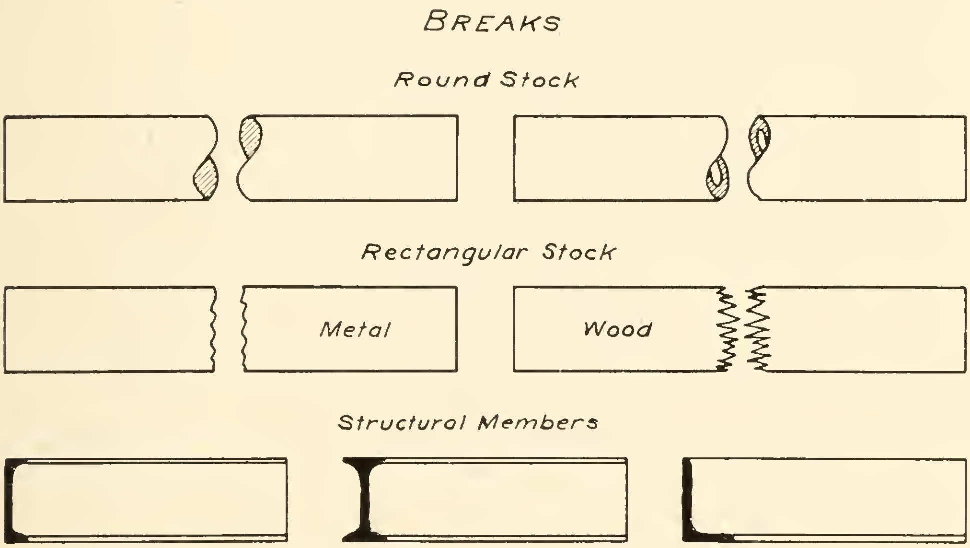


FIG. 68

thus to a certain extent prevent mistakes. With the use of the "Bill of Material" on the drawings, and copies of specifications at hand, there is no need to indicate the kind of metal by means of section lines as a general custom.

There is a very decided objection on the part of certain large firms to the above-mentioned custom and this objection is based upon the ground of economy. The form, or finished design, of machines is the result of constant change of detail, a process

of evolution based upon experience with various materials and with various sizes and shapes.

When one of these changes of detail is made it necessitates changing the old drawings, or making new ones, the former usually, if the change can be handled satisfactorily in this manner. All such changes are an expense but this cost may be reduced to a minimum if the change on the drawing is merely a change of material, for then the use of the "Bill of Material" permits us to change one symbol for another, as *C*–1 to *C*–*S* or *C*–1 to *B*–2, and the correction is complete except for the record of the change.

If we use a different type of section line for each metal and a sectional view is shown of the part to be changed, it is necessary to erase the section lines of this view on the tracing and replace them with the section lines of the new metal.

This process is so costly to firms with large numbers of drawings that it has led to the adoption of one style of section lines for all metals with the exception of bearing metals, such as Babbitt metal and similar alloys.

To restate this briefly, the use of different kinds of section lines to indicate the various metals is costly; it is also unnecessary, as we may clearly indicate materials on the "Bill of Material" from which specification clerks gain their information. Further, we may obtain the effect of contrast between parts by varying the spacing and the slope of section lines of the type shown for metal in Fig. 69.

In this illustration, Fig. 69, no attempt has been

made to show sections of all the *materials* used in engineering construction, but merely those needed for metals and some of the more common in use in building construction. It should be clearly understood also that what was mentioned above in reference to the use of different types of section lines for *metals* had reference only to manufacturers of some form of machinery and not to architectural construction.

At Fig. 70 is shown a *true* section of a flanged

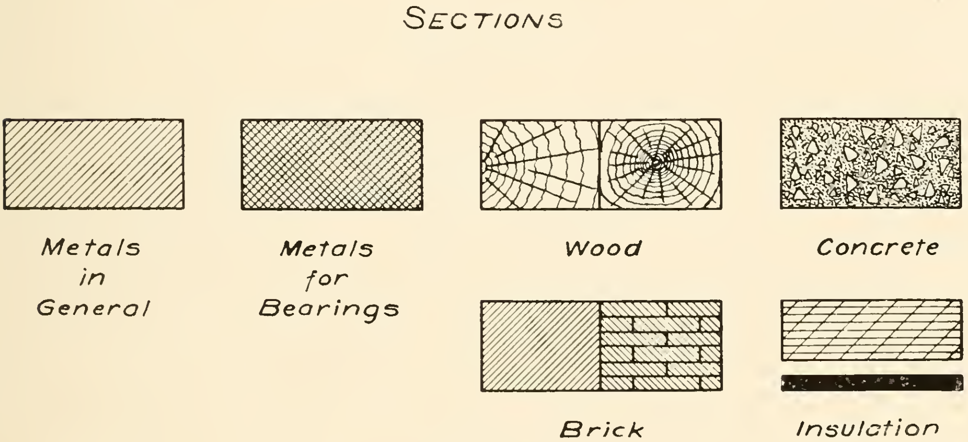


FIG. 69

pulley, this section being cut along the vertical center line of the side view. This section is in marked contrast with the illustration in Fig. 71, which shows a special section that is common for all pieces of this type, such as fly-wheels, pulleys and gear wheels with arms.

This section of the hand wheel is *not* a true section, but a conventional one which is more satisfactory for the use of the pattern maker and the draftsman as it shows a true cross section of the hub and the rim, though not of the wheel as a whole. This

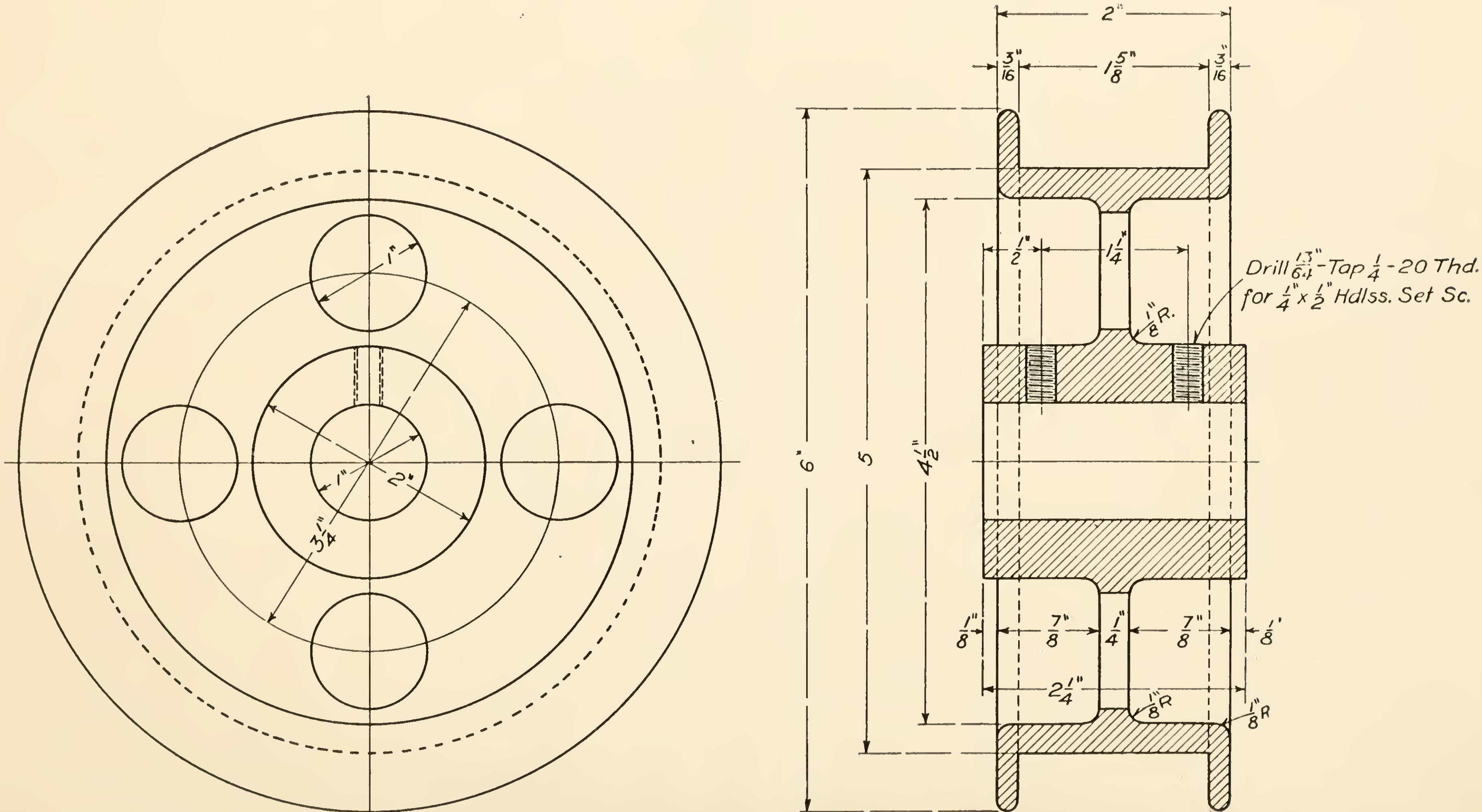

2"
3/16"
1 5/8"
3/16"
1"
2"
1"
3 1/4"
6"
5
4 1/2"
1/2"
1 1/4"
1/8" R.
Drill 13/64" - Tap 1/4 - 20 Thd. for 1/4" x 1/2" Hdlss. Set Sc.
1/8"
7/8"
1/4"
7/8"
1/8"
2 1/4"
1/8" R
1/8" R

FIG. 1-0

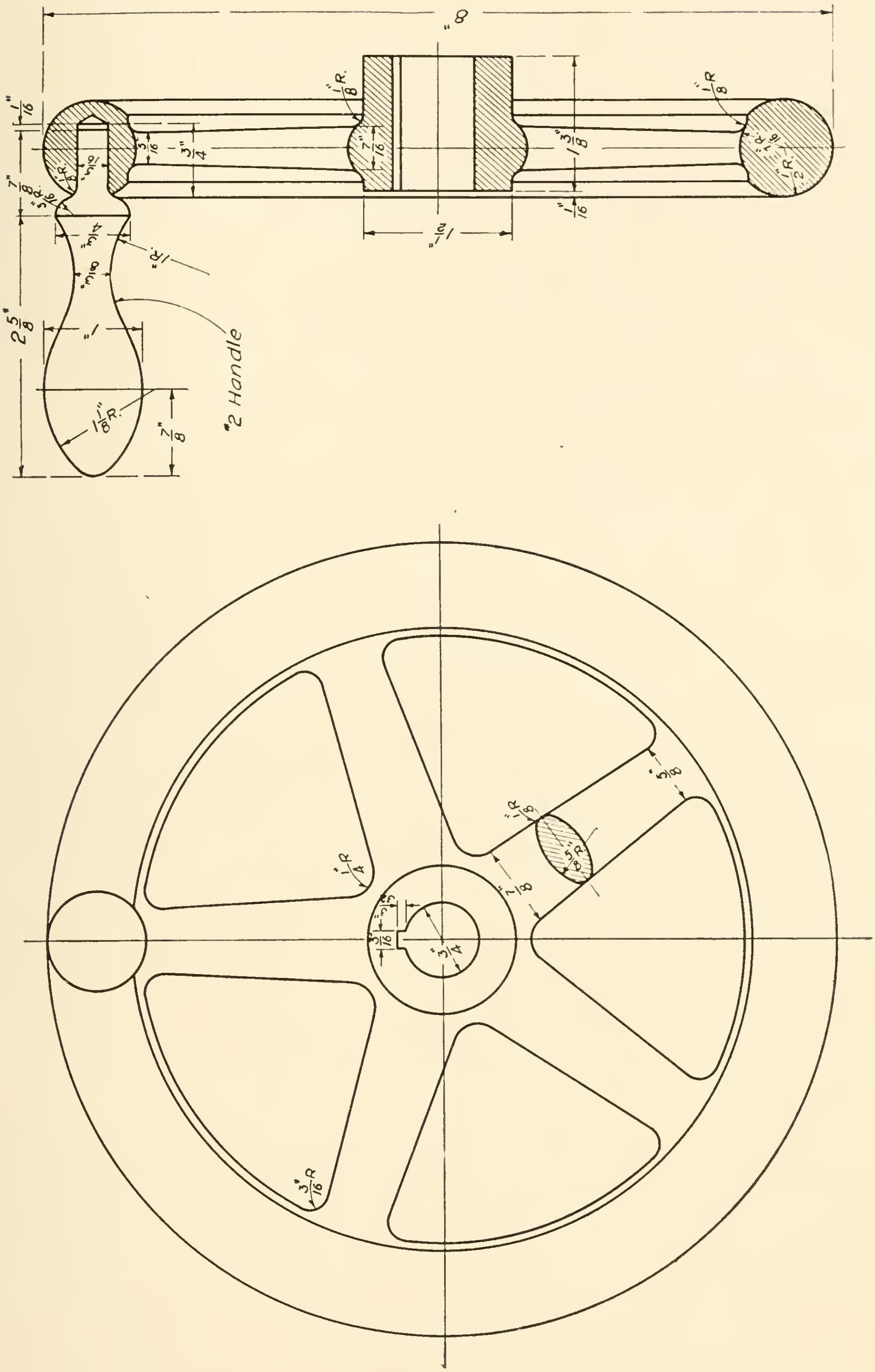


Fig. 71

method of sectioning is followed for pieces of this type regardless of the number of arms in the wheel. Further, the student should note that without the small cross section of the arm given in this manner, he would be unable to show the shape of this part.

Figure 72 illustrates the customary method of indicating where the sections are taken, by means of the lines *A–B* and *C–D*.

The armature spider shown in Fig. 73 is an il-

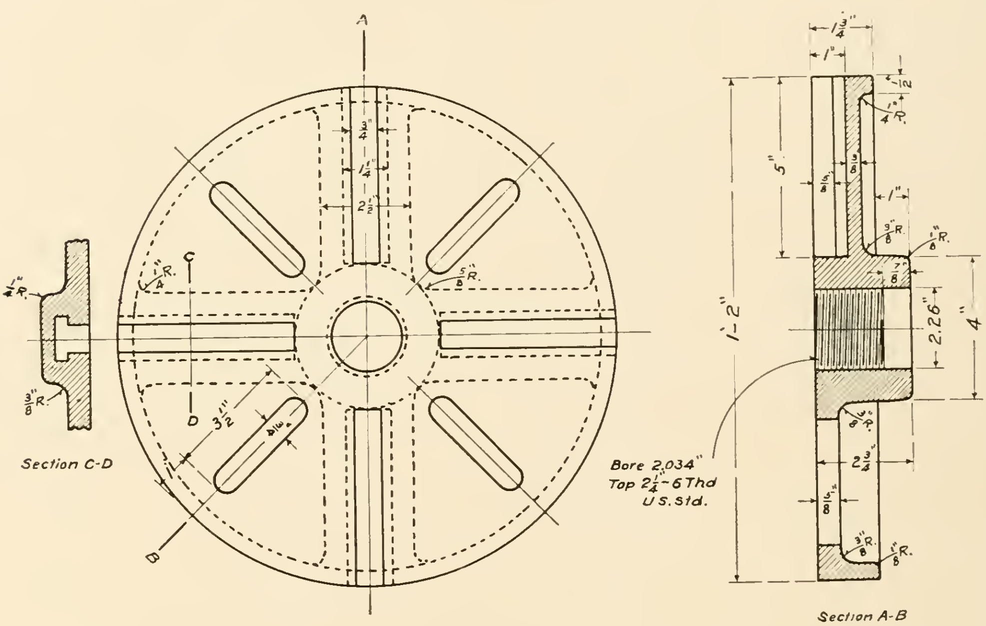
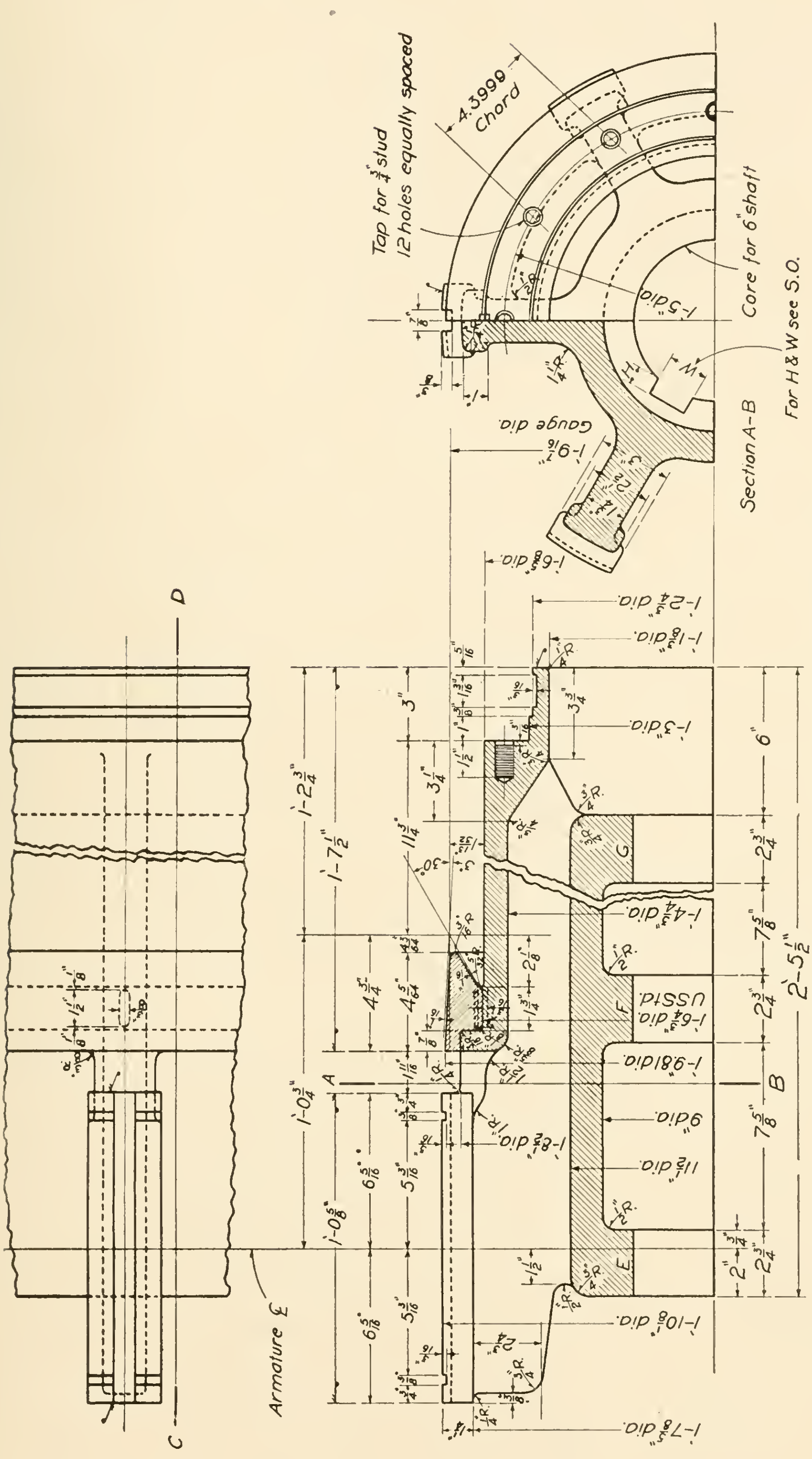


Fig. 72

lustration of special sectioning which shows true sections cut along the lines indicated. This illustration has value from at least two other points of view, one of which is that it shows a conventional method of making a working drawing of a large casting on a relatively small sheet of drawing paper, due to the fact that only a *part* (one half) of the casting is shown.

This type of working drawing is readily understood



For bores E, F & G see Stock Order

FIG. 73

by the workmen who are accustomed to note that many of the dimensions are given in *diameters*. This method of laying out working drawings has the decided merit of economy and may be considered as making advanced use of the "break" system.

Dimensions. — When dimensioning drawings it is of fundamental importance to place the dimensions in such a manner that they may be readily found and easily read. The figures must be printed clearly

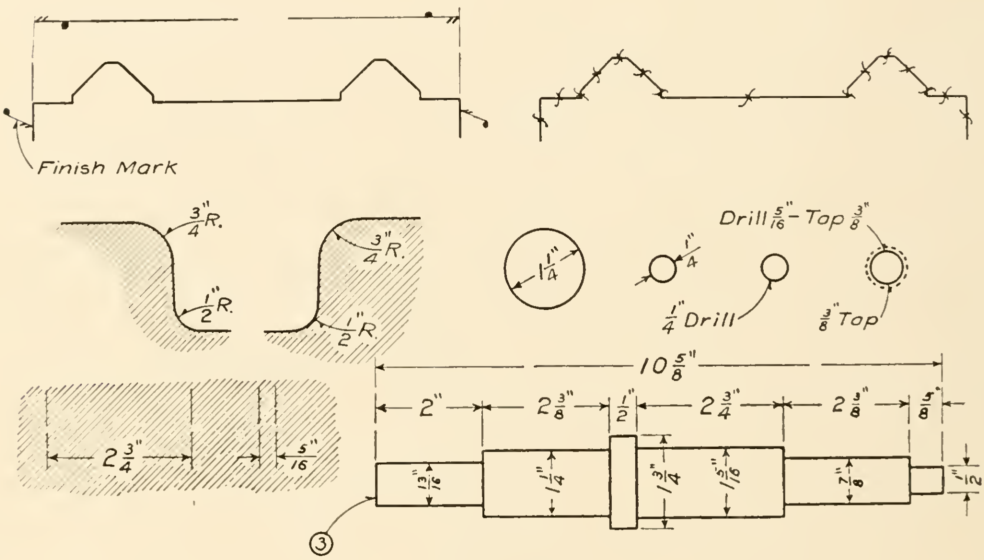


Fig. 74

and carefully and so arranged that there is no crowding; use plenty of space and plan the arrangement so that the various figures are placed in the best positions to give the size of the part they represent.

Figure 74 shows a number of excellent methods of placing dimensions so that they may be clearly seen. Note should be taken of the "finish mark," originated by Prof. George H. Follows, and the illustration of its use at the ends of the dimension

line, which indicates that all surfaces between these points are to be finished. The *f* which is in rather common use is contrasted on the adjoining figure.

Most of the suggestions indicated in Fig. 74 are made use of on the working drawing of the armature spider, Fig. 73, which is an excellent representation of correct methods of placing dimensions. When studying this illustration note should be taken of the fact that dimensions of twelve inches or greater are shown by feet and inches or fractions of an inch; but where the dimension is less than twelve inches it is indicated in inches. This custom is quite common, though some firms begin with twenty-four instead of twelve.

Standard Data. — In commercial drafting rooms a constant effort is made to devise ways and means to speed up production without, at the same time, lowering the standard quality of the product. One important means used to gain speed and to improve the quality of the product is: to provide *uniform methods* in the drafting room in the production of drawings. That is, all of the draftsmen use the same symbols, style of lettering, dimensioning and the same reference matter, and in all respects are required to follow the same standard.

In a drafting room where each draftsman handles his calculations in his own way regardless as to his neighbor's method of computing the same sort of a problem, and where there is much of this "go as you please" lack of method, such a thing as uniformity is out of the question. An infinitely better procedure is to determine the *best method* of handling

these problems which are constantly coming up for solution, and to make this method the standard.

This need of standardization has resulted in many firms forming a "Standard Department" within the drafting room organization, it being the duty of this department to determine which are the best methods, and to prepare this information in the form of reference sheets to which all draftsmen have access.

Usually these reference sheets, or "Standard Data" sheets as they are generally termed, are prepared in such form that little or no calculation is necessary on the part of the draftsman using them; generally speaking he refers to them for certain standard dimensions which are shown in tabular form.

The subject matter of these data sheets varies from the simplest matter to rather complex problems in some cases, but their purpose is to save time and to aid in producing uniform, accurate drawings.

Figures 75 and 76 illustrate two simple data sheets upon one of which the dimensions are given for standard sheets of an excellent size. These sheets may be prepared in blue print form and bound up in covers for convenience in handling.

Composite Drawing. — Any satisfactory method of representing subject matter in the drafting room which reduces the general expense of producing drawings is to be commended. By using what are known as "composite drawings," we may save making a large number of detail drawings.

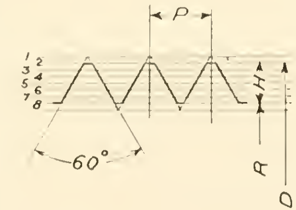
Firms that manufacture a standard line of machines usually design them in such a manner that

1'-0½"

For binding trim print to this line

U. S. STANDARD SCREW THREADS

Bolt Diameter		Thds. per In.	Dia at Root of Thread		Tap Drill, giving clearance of $\frac{1}{8}$ the height of thread triangle		Area at Root of Thd.	Safe load of Bolt. Based on fibre stress of 6000 Lbs. per Sq. In.
Inches	Inches		Inches	Nearest 64th	Inches	Nearest 64th	Sq. In.	Pounds
$\frac{1}{4}$	.250	20	.185	$\frac{3}{16}$	.196	$\frac{13}{64}$	.027	162
$\frac{5}{16}$	.312	18	.240	$\frac{15}{64}$	.252	$\frac{1}{4}$	.045	270
$\frac{3}{8}$	.375	16	.294	$\frac{19}{64}$	.307	$\frac{5}{16}$	.068	408
$\frac{7}{16}$	.437	14	.344	$\frac{11}{32}$	.360	$\frac{23}{64}$	.093	558
$\frac{1}{2}$	.500	13	.400	$\frac{13}{32}$	.417	$\frac{27}{64}$	.126	756
$\frac{9}{16}$	.562	12	.454	$\frac{29}{64}$	.472	$\frac{15}{32}$	.162	997
$\frac{5}{8}$	.625	11	.507	$\frac{1}{2}$	.527	$\frac{17}{32}$	.202	1210
$\frac{3}{4}$	750	10	.620	$\frac{5}{8}$	.642	$\frac{41}{64}$	.302	1810
$\frac{7}{8}$	875	9	731	$\frac{47}{64}$	.755	$\frac{3}{4}$	420	2520
1	1 000	8	.837	$\frac{27}{32}$	.865	$\frac{55}{64}$	.550	3300
$1\frac{1}{8}$	1.125	7	.940	$\frac{15}{16}$	.970	$\frac{31}{32}$	694	4160
$1\frac{1}{4}$	1.250	7	1.065	$1\frac{1}{16}$	1.095	$1\frac{3}{32}$	.893	5350
$1\frac{3}{8}$	1.375	6	1.160	$1\frac{5}{32}$	1.215	$1\frac{7}{32}$	1.057	6340
$1\frac{1}{2}$	1.500	6	1.284	$1\frac{9}{32}$	1.345	$1\frac{11}{32}$	1.295	7770
$1\frac{5}{8}$	1.625	$5\frac{1}{2}$	1.389	$1\frac{25}{64}$	1.428	$1\frac{27}{64}$	1 515	9090
$1\frac{3}{4}$	1.750	5	1.491	$1\frac{31}{64}$	1.534	$1\frac{17}{32}$	1.746	10470
$1\frac{7}{8}$	1.875	5	1.616	$1\frac{39}{64}$	1.659	$1\frac{21}{32}$	2.051	12300
2	2.000	$4\frac{1}{2}$	1 712	$1\frac{23}{32}$	1.760	$1\frac{49}{64}$	2.302	13800
$2\frac{1}{4}$	2 250	$4\frac{1}{2}$	1.962	$1\frac{61}{64}$	2.010	$2\frac{1}{64}$	3.023	18100
$2\frac{1}{2}$	2 500	4	2.176	$2\frac{11}{64}$	2.230	$2\frac{15}{64}$	3.719	22300
$2\frac{3}{4}$	2.750	4	2.426	$2\frac{27}{64}$	2.480	$2\frac{31}{64}$	4.620	27700
3	3.000	$3\frac{1}{2}$	2.629	$2\frac{5}{8}$	2.691	$2\frac{11}{16}$	5.428	32500



Pitch $P = \frac{1}{\text{Nbr. Thds per in.}}$

Depth of Thd $H = P \times .6495$

Root dia. $R = \frac{1.299}{\text{Nbr. Thds per in.}}$

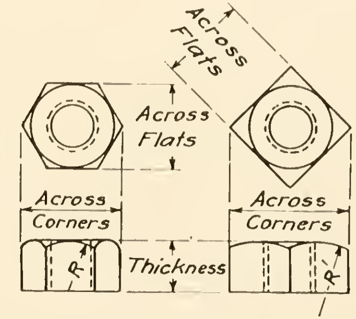
Tap Drill $= D \frac{1.0825}{\text{Nbr. Thds. per in.}}$

THE JOHN W. ROBERTS COMPANY, Piqua, O. S.D_1036

FIG. 75

U.S. STANDARD NUTS & BOLTS

Bolt		Diameters				Thickness	
Diameter	Thds per In.				Bottom of Thread		
.25	20	.5	.578	.707	.1850	.25	.25
.3125	18	.5938	.686	.840	.2403	.3125	.2969
.375	16	.6875	.794	.972	.2938	.375	.3438
.437	14	.7813	.902	1.105	.3447	.4375	.3906
.5	13	.875	1.011	1.237	.4001	.5	.4375
.562	12	.9688	1.119	1.370	.4542	.5625	.4844
.625	11	1.0625	1.227	1.502	.5069	.825	.5313
.75	10	1.25	1.444	1.768	.6201	.75	.625
.875	9	1.4375	1.660	2.033	.7307	.875	.7188
1.	8	1.625	1.877	2.298	.8376	1.	.8125
1.125	7	1.8125	2.093	2.563	.9394	1.125	.9063
1.25	7	2.	2.310	2.828	1.0644	1.25	1.
1.375	6	2.1875	2.527	3.093	1.1585	1.375	1.0938
1.5	6	2.375	2.743	3.358	1.2835	1.5	1.1875
1.625	5.5	2.5625	2.960	3.623	1.3888	1.625	1.2813
1.75	5	2.75	3.176	3.889	1.4902	1.75	1.375
1.875	5	2.9375	3.393	4.154	1.6152	1875	1.4688
2.	4.5	3.125	3.609	4.419	1.7113	2.	1.5625
2.25	4.5	3.5	4.043	4.949	1.9613	2.25	1.75
2.5	4	3.875	4.476	5.479	2.1752	2.5	1.9375
2.75	4	4.25	4.909	6.010	2.4252	2.75	2.125
3.	3.5	4.625	5.342	6.540	2.6288	3.	2.3125
3.25	3.5	5.	5.775	7.070	2.8788	3.25	2.5
3.5	3.25	5.375	6.208	7.600	3.1003	3.5	2.6875



Dia Across Flats $= 1\frac{1}{2} \times$ Bolt dia. $+ \frac{1}{8}''$

Hex. Dia. Across Corners $= 1.156 \times$ Flat dia.

Sq. Dia. Across Corners $= 1.414 \times$ Flat dia.

Thickness of Nut = Bolt dia.

Thickness of Bolt Hd. $= \frac{1}{2}$ of Flat dia

Not U.S. Std.

Radius R = Bolt dia.

Radius $R' = 1\frac{1}{2}$ Bolt dia.

THE JOHN W. ROBERTS COMPANY, Piqua, O. SD_1037

FIG. 76

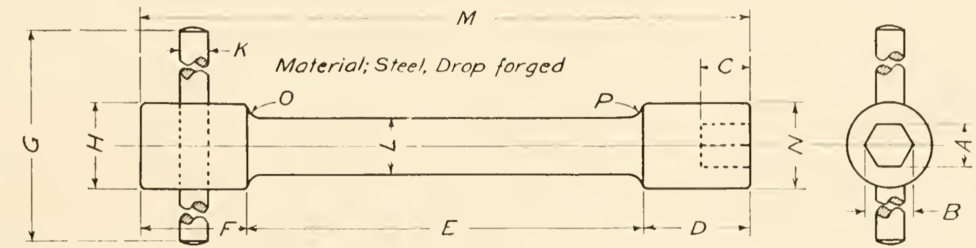
certain details of these machines are just alike except as to size. This being the case, a drawing may be produced which represents all sizes of a particular detail. As it would be impracticable to place the dimensions of all sizes on this one figure, letters are used to designate the various dimensions. Below the drawing of the piece a table is laid out with these letters as headings, and under each letter the dimensions are given for each size of the piece illustrated.

As an illustration of the saving by this method, the composite drawing shown in Fig. 77 furnishes information for the production of twelve socket wrenches of different sizes, this one drawing taking the place of twelve, and after one is familiar with the method, this type of drawing is as readily and easily used as a separate detail drawing.

These drawings are of value in the drafting room for reference purposes, and they may be prepared upon the same size sheets as standard data, and used as such. They may be furnished to the shop-men who produce the parts, as any notes as to material, finish, etc., may be placed upon a drawing of this kind as well as upon any other working drawing.

Abbreviations. — It is a common practice in drafting rooms to abbreviate words and terms for the purpose of saving time and space when printing notes on drawings. In furnishing the following list of abbreviations our aim is to present some of those in quite general use but with no pretension that this is a complete list:

SOCKET WRENCH



Bolt Diameter	A	B	C	D	E	F	G	H	K	L	M	N	O	P
1/4	3/8	7/16	7/16	15/16	3 1/2	15/16	7	3/4	1/4	1/2	5 3/8	3/4	1/8	1/8
5/16	15/32	35/64	1/2	1	4 1/4	1	8	7/8	3/8	9/16	6 1/4	7/8	1/8	1/8
3/8	9/16	21/32	9/16	1 1/16	4 1/4	1 1/16	8	7/8	3/8	5/8	6 3/8	1	1/8	1/8
1/2	3/4	27/32	5/8	1 1/8	4 3/4	1 1/8	9	1 1/8	3/8	3/4	7	1 1/4	3/16	3/16
5/8	15/16	1 5/64	3/4	1 1/4	4 3/4	1 1/4	9	1 3/8	1/2	1	7 1/4	1 1/2	3/16	3/16
3/4	1 1/8	1 19/64	7/8	1 3/8	5	1 3/8	10	1 3/4	1/2	1 1/4	7 3/4	1 3/4	3/16	3/16
7/8	1 5/16	1 1/2	1	1 1/2	5	1 1/2	10	1 3/4	1/2	1 3/8	8	2	3/16	1/4
1	1 1/2	1 47/64	1 1/8	1 5/8	5 1/4	1 1/2	11	2	1/2	1 1/2	8 3/8	2 3/8	1/4	3/8
1 1/4	1 7/8	2 5/32	1 3/8	1 3/4	5 1/4	1 1/2	11	2 1/4	1/2	1 3/4	8 1/2	2 3/4	1/4	3/8
1 1/2	2 1/4	2 19/32	1 5/8	1 7/8	5 1/2	1 1/2	12	2 1/2	1/2	2	8 7/8	3 3/8	1/4	1/2
1 3/4	2 5/8	3 1/32	1 7/8	2	5 1/2	2	13	2 3/4	9/16	2 1/4	9 1/2	3 7/8	1/4	1/2
2	3	3 15/32	2 1/4	2 3/8	5 1/2	2 1/4	14	3 1/4	9/16	2 3/4	10 1/8	4 1/4	1/4	1/2

THE JOHN W. ROBERTS COMPANY, Piqua, O. CD-1037

FIG. 77

A. C.	Alternating Current
Br.	Brass
Bz.	Bronze
C. I.	Cast Iron
C. S.	Cast Steel
C. R.	Cold rolled (Machine Steel)
C. L. or C.	Center Line
Csk.	Countersink
Cbr.	Counterbore
C. P.	Circular Pitch
D. and dia.	Diameter
D. C.	Direct Current
H. P.	Horse-power
Hd.	Head
Hdlss.	Headless
Hex.	Hexagon
In.	Inch
I.	I-Beam
K. W.	Kilowatt
L.	Angle
L. H.	Left hand
M. S.	Machine Steel
M. I.	Malleable Iron
Nbr. and No.	Number
P.	Pitch
Pat.	Pattern
Pl.	Plate
R. and Rad.	Radius
R. P. M.	Revolutions per minute
R. H.	Right hand
Rd.	Round
Req.	Required
Sc.	Screw
Sq.	Square
Std.	Standard
T.	Teeth
Thd.	Thread
V.	Volt
W. I.	Wrought Iron
W. S.	Wrought Steel

Bill of Material. — A device which is known as the "Bill of Material" is used for listing in table form the various items shown on a working drawing. This feature which is illustrated in Fig. 78 is generally placed upon an assembly drawing, though under certain conditions it is made upon a separate sheet, given a drawing number, and is included as one of a set of drawings.

The make-up of the bill of material varies with the subject matter, but should contain a list of all items shown on the drawing, or drawings, as the case may be. The name and material of each item, the number required, the pattern, tool and drawing numbers, usually form the headings for the various columns.

The item number in the bill of material corresponds with the number placed on the part indicated; in

this manner each part is listed so that the specification clerks may obtain the information which they need and there is little chance for an item to be overlooked. The common practice when numbering parts is to throw a small circle around the number and to connect this circle with the part by means of a pointer as indicated in the illustration, Fig. 74.

Dwg. No. 13625 BILL OF MATERIAL Sub No. 1			
Item No.	Description and Material	Pat. No.	Req.
1	B.H. Bracket, C.I.	N 7364	1
2	B.H. Bracket, C.I.	N 7365	1
3	#4 X $2\frac{3}{4}''$ Taper pin, C.R.		2
4	$\frac{3}{8}''$ X $1\frac{1}{4}''$ Set Sc. M.S.		4
5	Bushing, $1\frac{15}{16}''$ of $\frac{7}{8}''$ X $\frac{11}{16}''$ Brass Tubing.		4
6	Ins. Bushing, $3\frac{5}{16}''$ of $\frac{11}{16}''$ X .51 Micarta Tubing.		4
7	Washer, S# 2892.		4
8	$\frac{1}{2}''$ Lock Washer, S# 52440.		4
9	$\frac{1}{2}''$ X $5\frac{1}{2}''$ Stud, C.R.		4
10	Washer plate, treated F.B., S# 47282.		2
11	Washer plate, fibre, S# 47281.		4
12	Washer, W.I., S# 47280.		4
13	Insulating Cap, S# 47278.		4
14	Washer plate, fibre, S# 47279.		4
15	Washer plate, treated F.B., S# 47283		2
16	B.H. Rod, $8\frac{1}{8}''$ of $1\frac{1}{4}''$ Rd. Br. Rod.		2

Fig. 78

Reverse Curves. — It frequently happens that certain parts of machines are so shaped that a reverse curve is made use of in forming various surfaces. By a reverse curve, we mean a curve formed by joining two arcs thrown in opposite directions. When this occurs (except for small radii), the radii should *not* touch direct, but should be joined by a tangent straight line. This procedure gives a curve which is decidedly more pleasing to the eye than

would have been the case had the radii been joined without the tangent straight line.

Checking. — After a working drawing is completed, but before prints of it are sent to the shop, this drawing must pass through the hands of an individual whose duty it is to catch all errors of omission and commission. This individual, known as a "checker," studies the drawing in an impersonal fashion and endeavors to find each fault and have it corrected, for if drawings were to reach the shop without this procedure many more costly mistakes would be made, as it seems to be nearly impossible for a draftsman to properly check his own drawings.

CHAPTER XI

WORKING DRAWINGS

Working Drawings. — In view of the information given in the preceding chapter on Drafting Room Conventions it should not be necessary to enter into much detail upon the subject of our present chapter, Working Drawings. There are, however, several additional features which should be mentioned before we take up the problems which will follow.

Working drawings consist in the main of detail and assembly drawings. The former, as the name implies, is a working drawing from which the shop men produce the parts or details of some mechanism. An assembly drawing shows the parts assembled together and is used mainly as a guide for the shop assembling department, though for certain classes of work, assembly drawings are used also as the production drawings for some of the parts shown on the assembly.

It is a custom in most plants which produce some form of machinery to divide these machines into sections. This division is a great convenience in the drafting room and is often made use of in the shop as an aid in production, by having departments which produce only their section of the machines.

We may illustrate this custom by means of an engine lathe which is usually divided into the fol-

lowing sections: Headstock, Tailstock, Compound Rest, Carriage, Apron, Bed and Legs, drawings of these sections being grouped under the heading of the section as detail or assembly drawings.

Scale. — When planning a drawing one of the first points which it is necessary to settle is the "scale" or size we shall make our layout. Generally we make drawings to as large a scale as may be desirable to show clearly the details of the object, always keeping in mind the necessity to show the dimensions to good advantage.

For drawings of machinery in general, the scales used are based upon the inch, and those in most common use are: full size, $\frac{1}{2}$ size and $\frac{1}{4}$ size. For buildings, bridges, and very large machinery, the scale is based upon the foot, and is usually indicated as $\frac{1}{4}'' = 1'$, $3'' = 1'$, etc.

By either method, the student should persistently endeavor to learn to read the different scales *by eye* and should *not* determine the proportions of the figure he is drawing by mathematical calculations. If the eye is trained to locate any dimension upon the scale (rule), regardless of whether the student is drawing full or quarter size, the chances for error are greatly decreased, for the eye may be trained to detect error before even the mind has quite grasped what the error is.

Titles. — Working drawings are usually identified by means of the title and the drawing number, both means being especially needed in keeping the records of a drafting room. The title is generally placed in the lower-right hand corner of the drawing sheet

and usually contains the firm name and address, a name which indicates the subject matter of the drawing, a drawing number, the scale the drawing has been made, and in addition some provision for keeping a record of changes, etc.

At Fig. 79 is shown a standard title and record

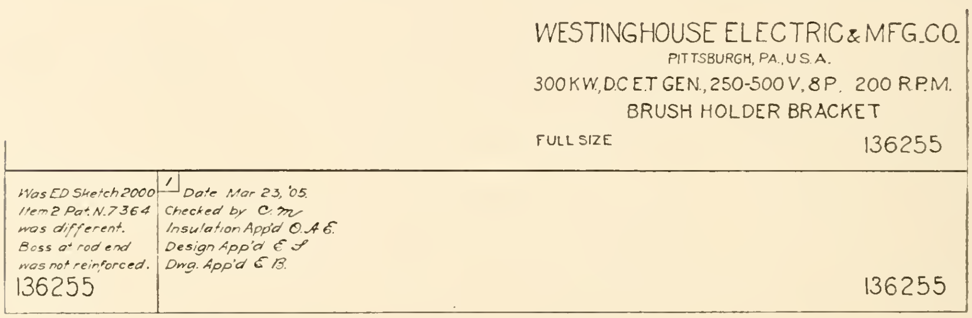


Fig. 79

strip of a well-known firm, which design has proven highly satisfactory after many years of experience with thousands of drawings in use.

For the working drawings which follow it is suggested that we use a *title strip* similar to that shown in Fig. 80, as this is a simple form and contains all the information needed for our purpose while leaving the body of the sheet free for the drawing.

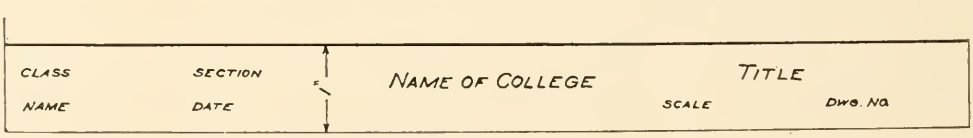


Fig. 80

In the case of each assembly drawing among the following problems, the student is expected to prepare a bill of material to be placed upon these drawings. Where the same pattern may be used for the halves of a casting, do not fail to use it, but in case the halves are to be finished in a slightly different man-

ner, they should have separate item numbers. Do not overlook any items but see that each part is numbered and listed.

Problems. — Make a working detail drawing from the clamp sketch of Fig. 31 in Chapter No. VI. Scale, full size. Title, Clamp.

Make a detail drawing from the sketch of the

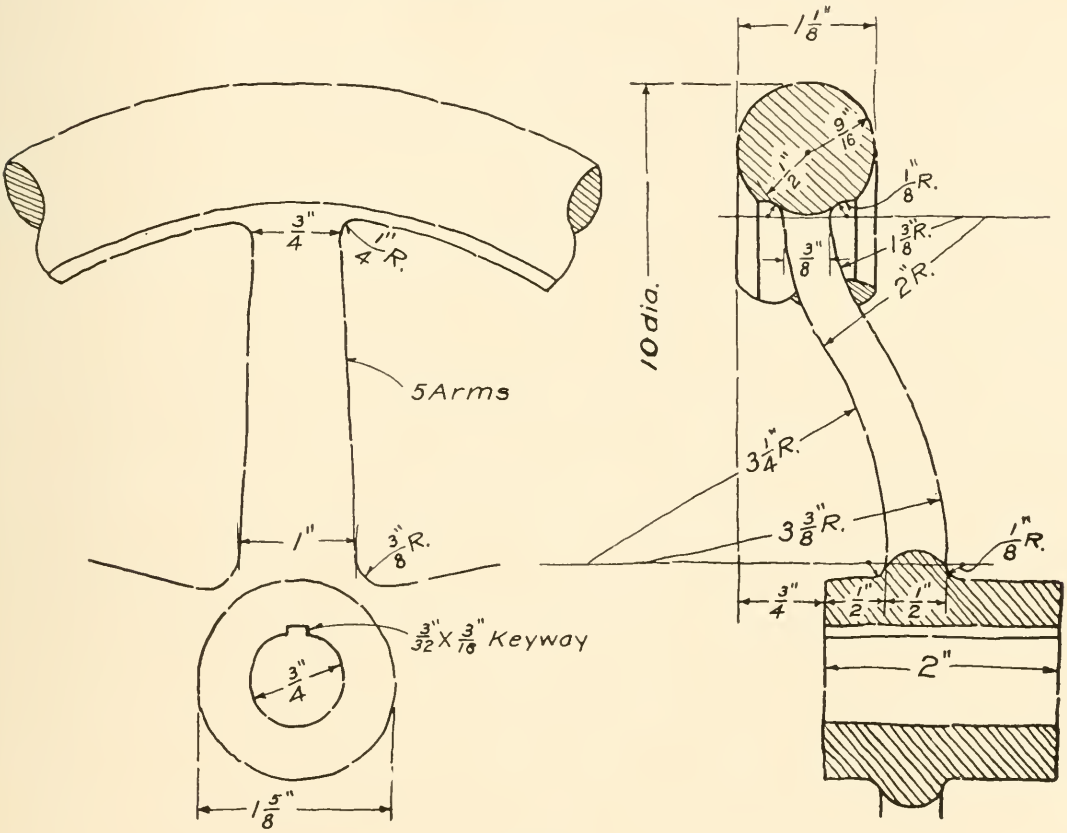


Fig. 81

shaft support, Fig. 32 Chapter No. VI. Scale, full size. Title, Shaft Support.

Make a detail drawing from the sketch of the tool rest, Fig. 33 Chapter No. VI. Scale, full size. Title, Tool Rest.

Make a detail drawing from the pulley sketch of Chapter No. VI. This drawing to show a side

view and a *sectional view,* the latter to be made in accordance with the conventional method customary for subjects of this type. Scale, ½ size. Title, 14″ Pulley.

Make a detail drawing of the hand wheel shown in

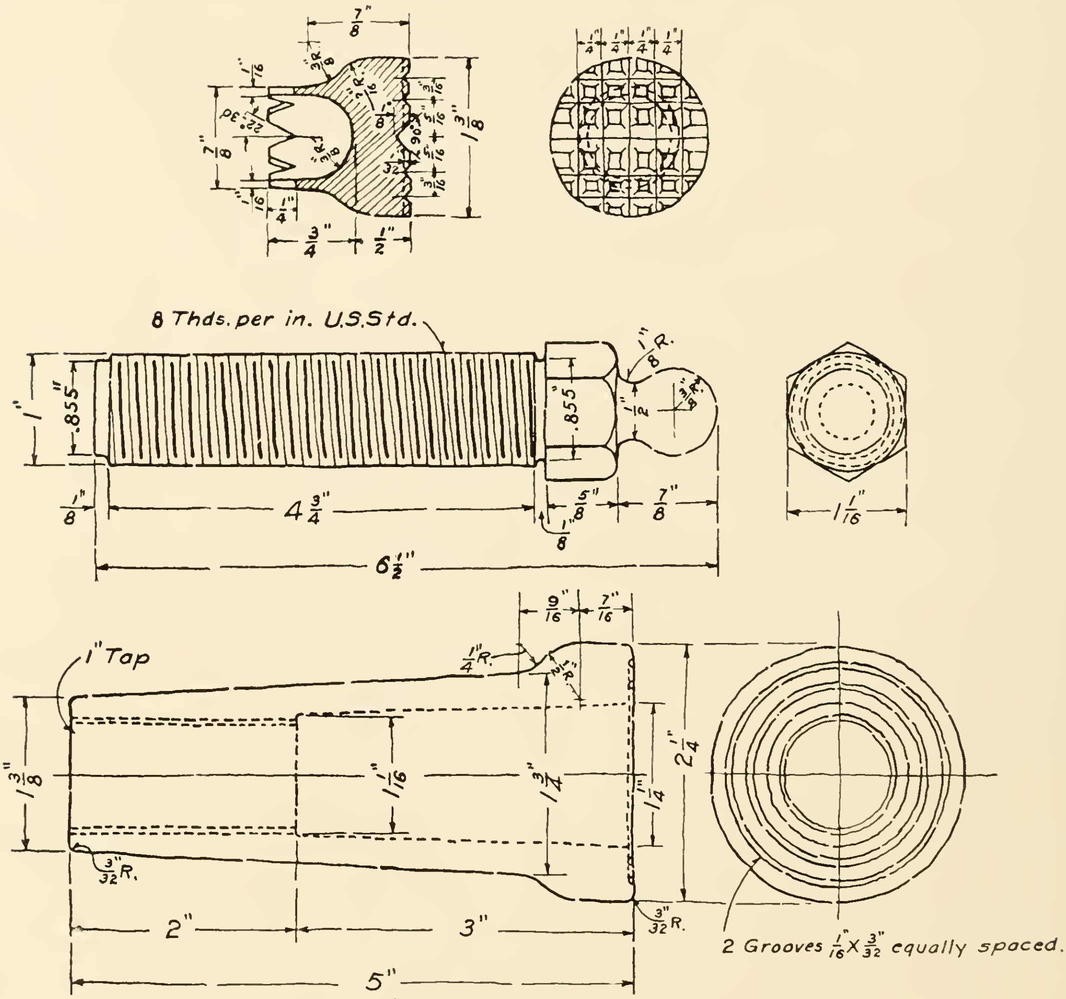


Fig. 82

Fig. 81. Scale, full size. Title, 10″ Hand Wheel.

From the sketches shown in Fig. 82 make a working drawing which includes both details and an assembly of this screw jack. Scale, full size. Title, Screw Jack.

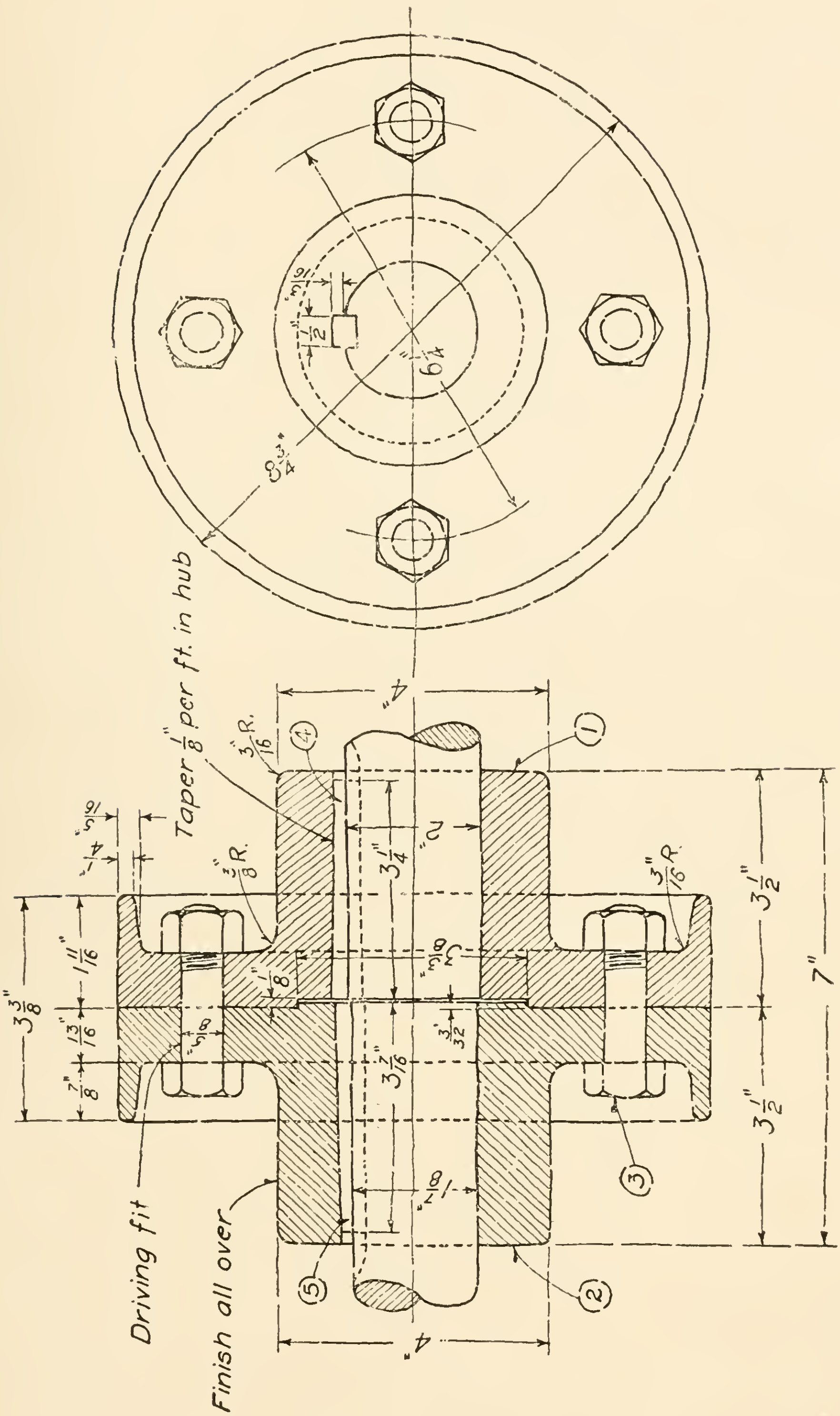

Taper 1/8" per ft. in hub
Driving fit
Finish all over
8 3/4"
6 1/4"
4"
4"
7"
3 1/2"
3 1/2"
3 3/8"
1 11/16"
13/16"
7/8"
3 1/4"
3 7/16"
1 7/8"
2"
1/2"
3/16"
3/16" R.
3/8" R.
3/32"
1/8"
1
2
3
4
5

Fig. 83

From the sketch illustrated in Fig. 83 make an assembly drawing of the coupling. The bill of material should include each item shown except the portions of the shafts. Scale, full size. Title, Safety Flange Coupling.

From the sketch illustrated in Fig. 84 make an assembly drawing of the coupling. It is expected that the student will *not* copy the views as they are shown, but will lay them out as follows: Section *A–B*, to be shown as at present, except that the view is to be revolved on its axis (clockwise) 90 degrees or one-fourth turn, bringing the bolts *horizontal*, with the nuts on the right-hand side. This change in Section *A–B* will necessitate the lengthwise view being revolved on its axis one-fourth turn toward us, bringing the ends of the nuts on all six bolts into view. Scale, $\frac{1}{2}$ size. Title, Compression Shaft Coupling.

Make a detail drawing of the lathe leg shown in Fig. 85. Scale, $\frac{1}{4}$ size. Title, 12″ Speed Lathe — Leg Details.

Make a detail drawing of the bed shown in Fig. 86. Scale, $\frac{1}{2}$ size. Title, 12″ Speed Lathe — Bed Details.

Make a detail drawing of the rest details shown in Fig. 87. Scale, $\frac{1}{2}$ and full size. Title, 12″ Speed Lathe — Tool Rest Details.

From the details shown in Figs. 87 and 88, make an assembly drawing. Scale, $\frac{1}{2}$ size. Title, 12″ Speed Lathe — Tool Rest Assembly.

Make a detail drawing of the details shown in Fig. 89. Scale, full size. Title, 12″ Speed Lathe — Tailstock Details.

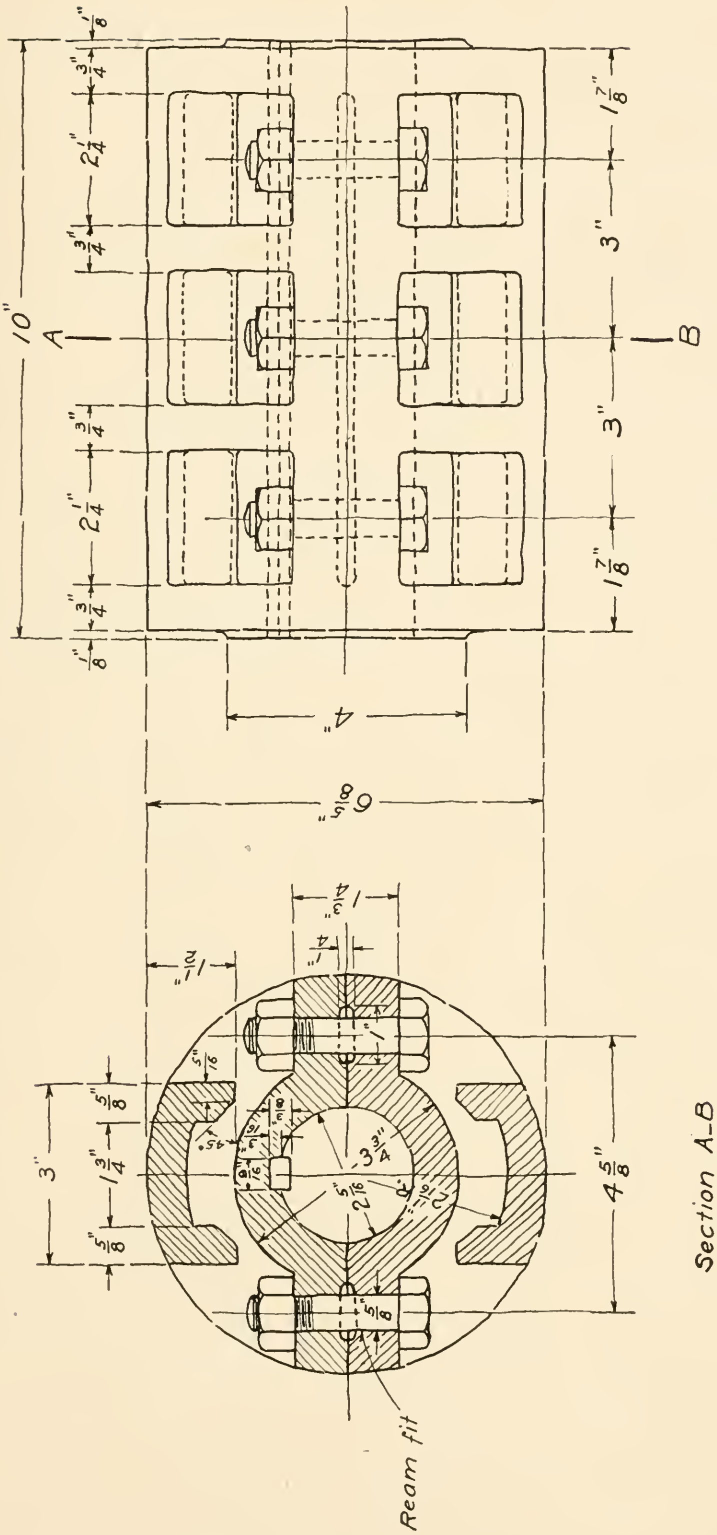


Fig. 84

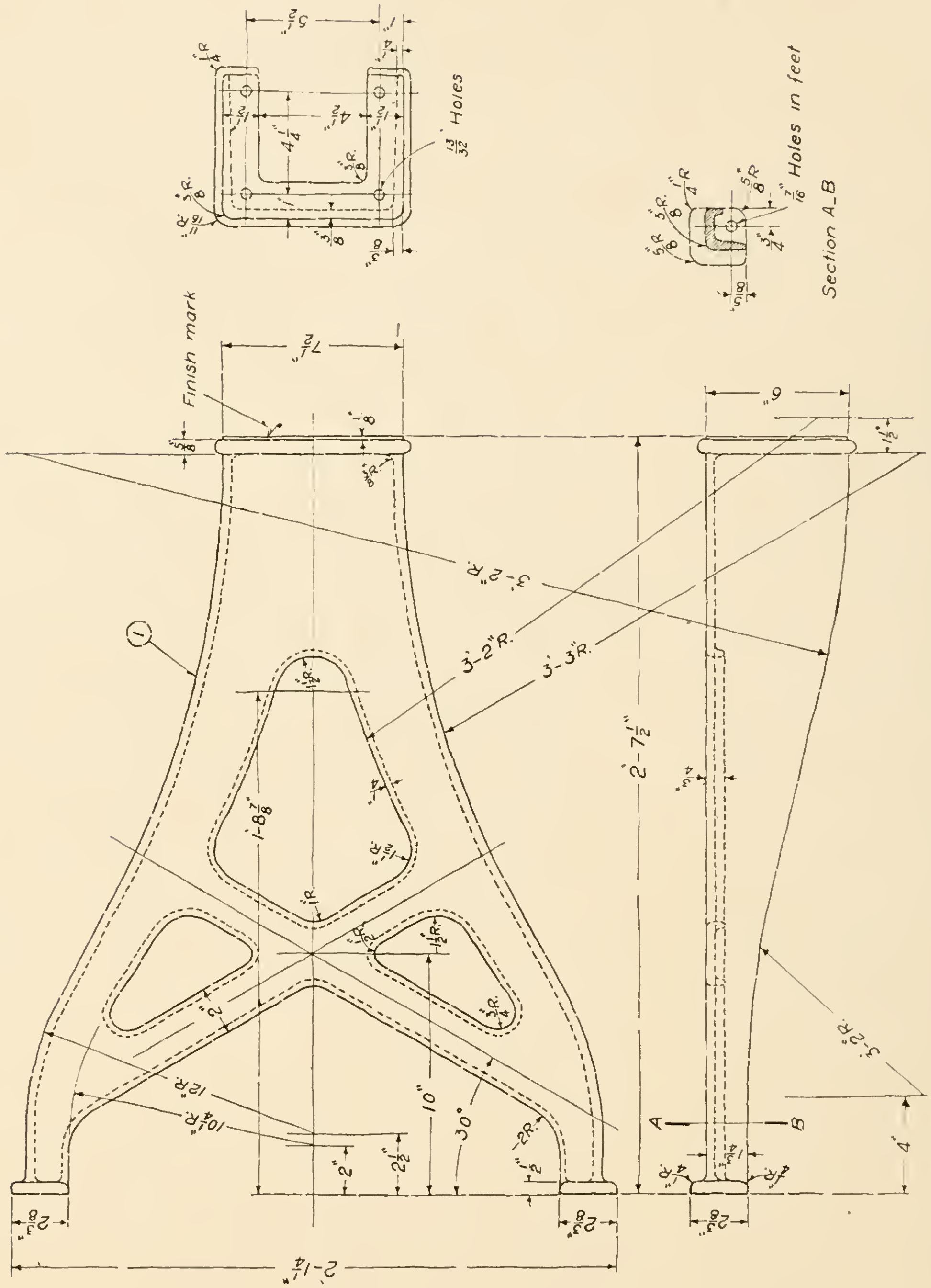

Finish mark
$\frac{13}{32}$" Holes
$\frac{7}{16}$" Holes in feet
Section A_B

Fig. 85

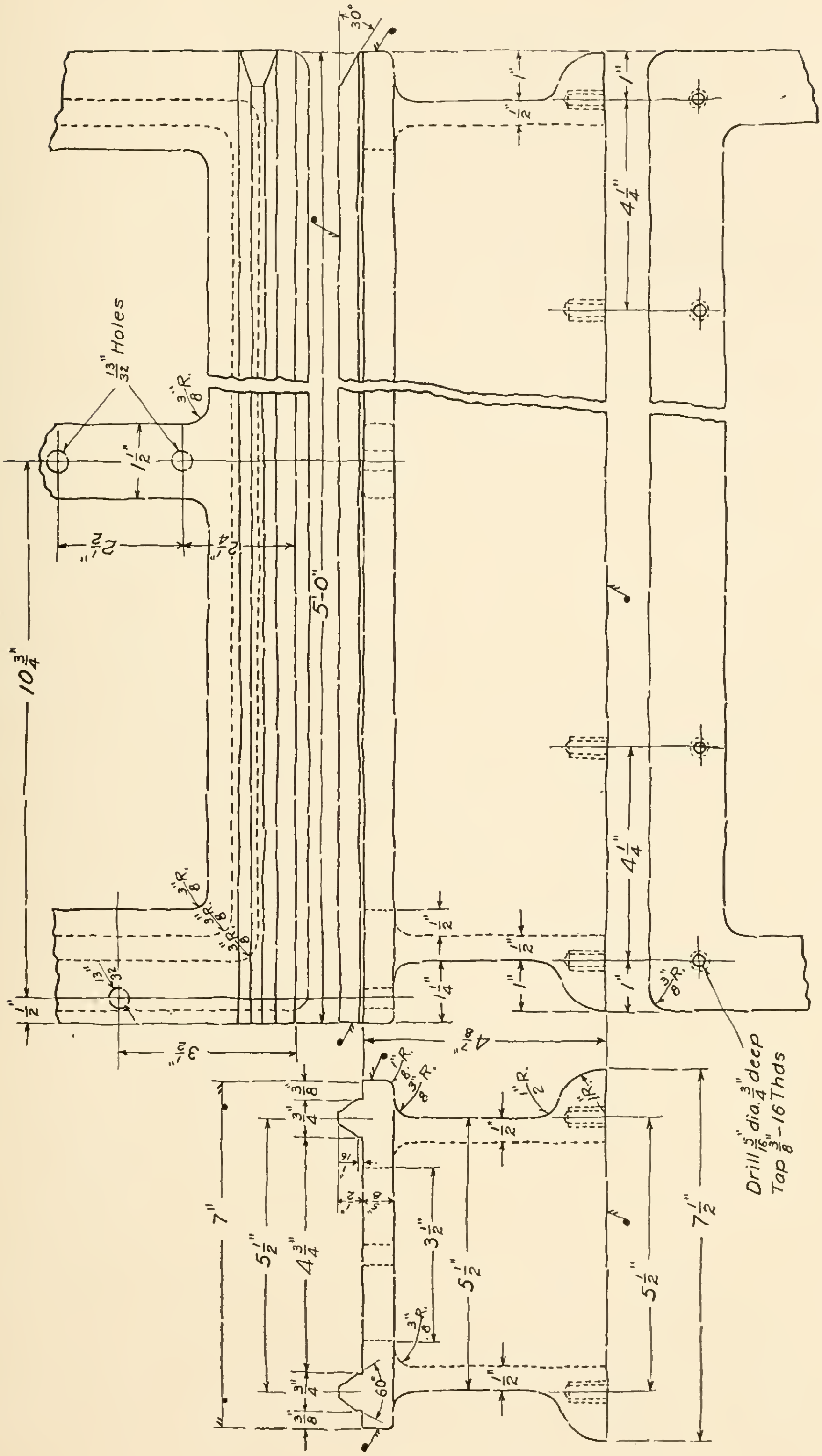


Fig. 86

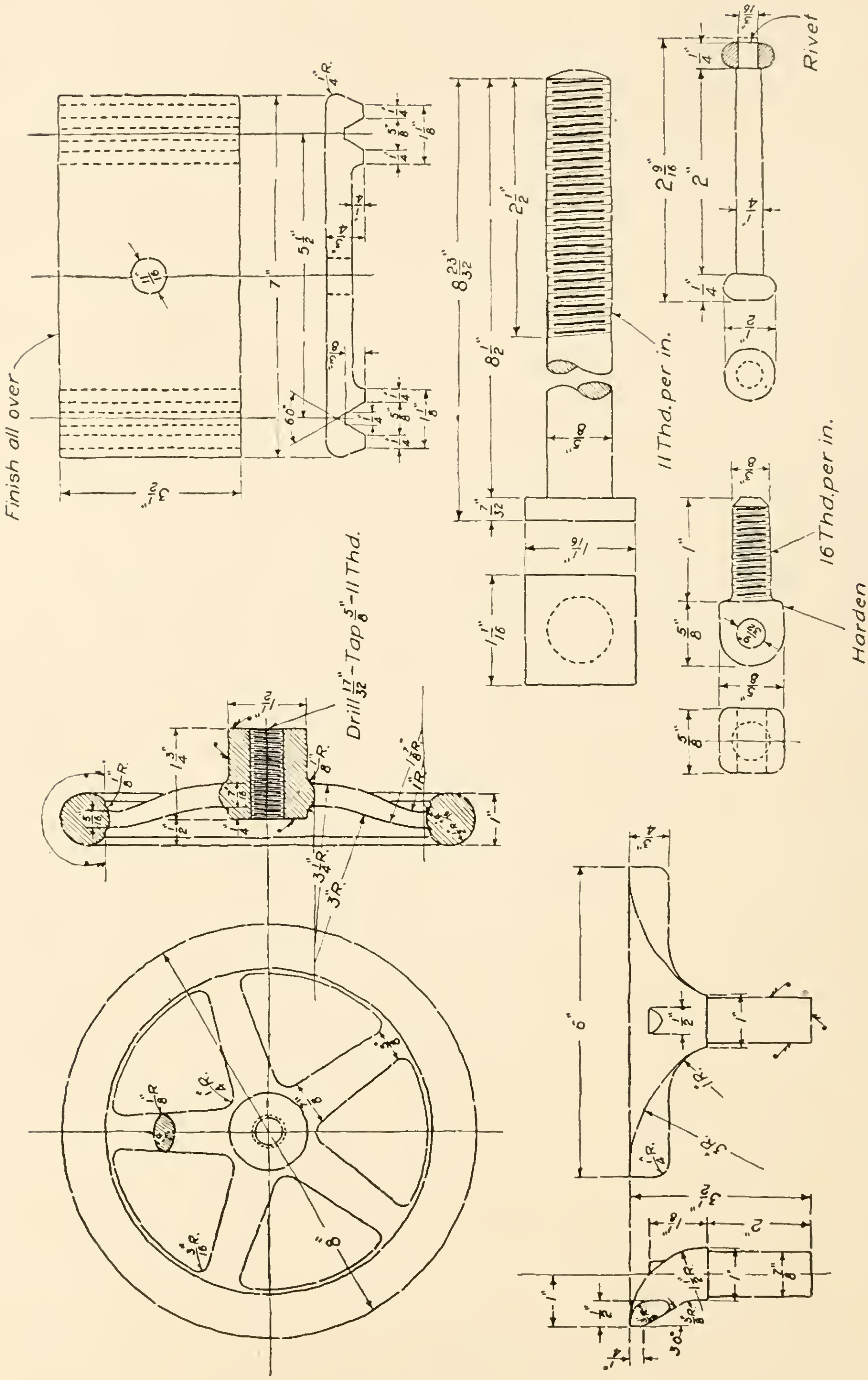

Finish all over
11 Thd. per in.
Rivet
16 Thd. per in.
Harden
Drill 17/32"-Tap 5/8"-11 Thd.

FIG. 87

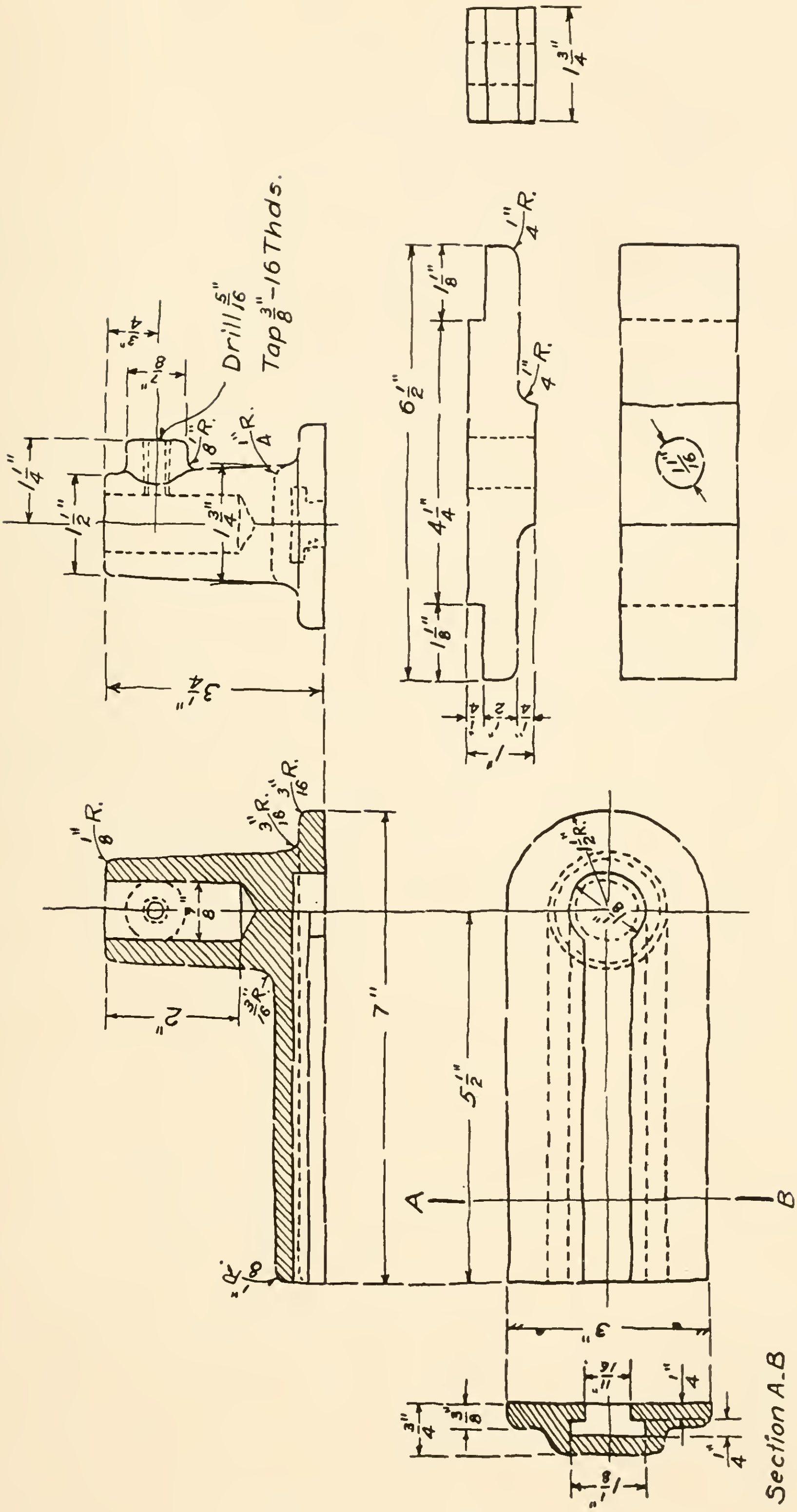


Fig. 88

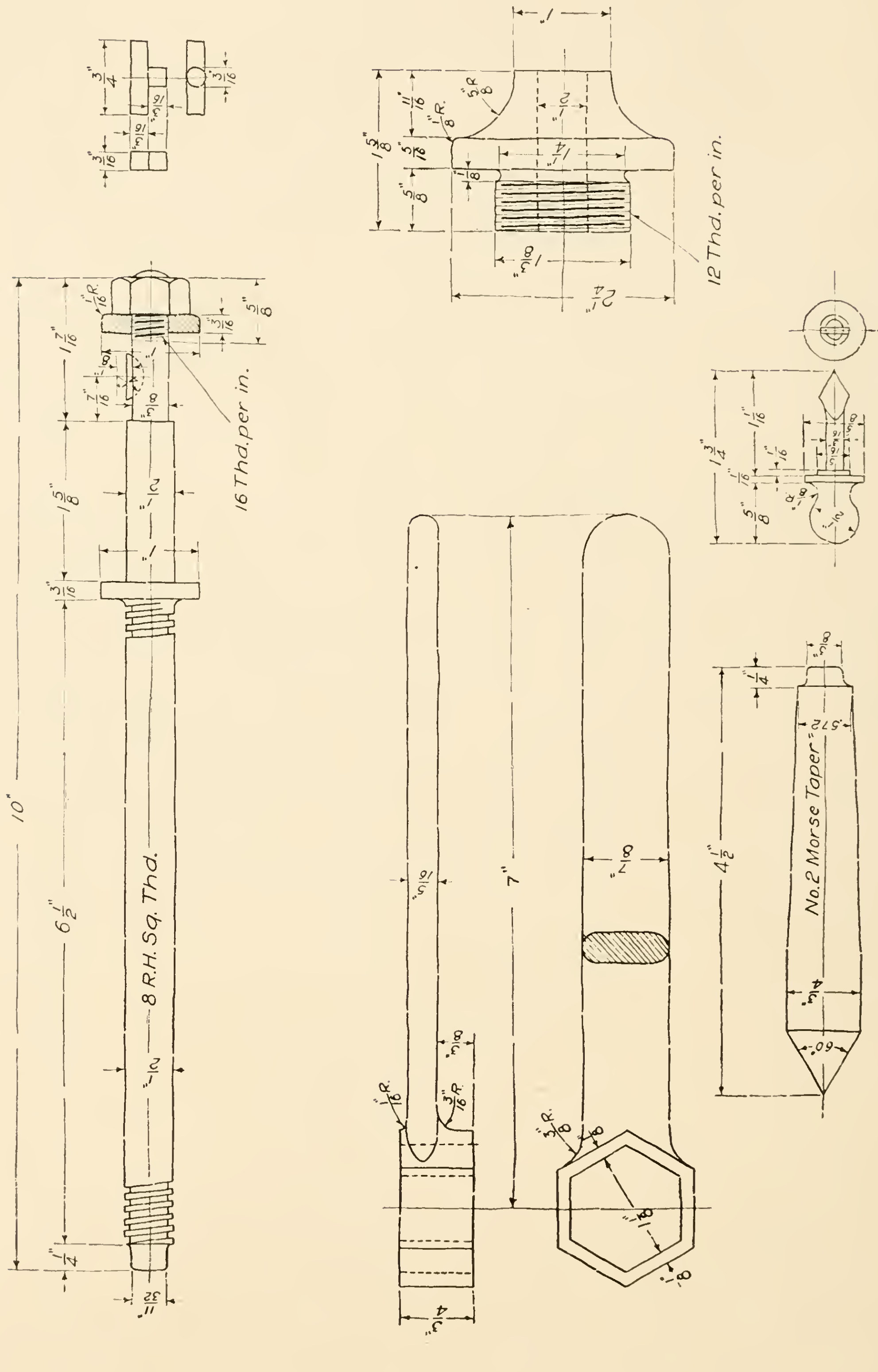
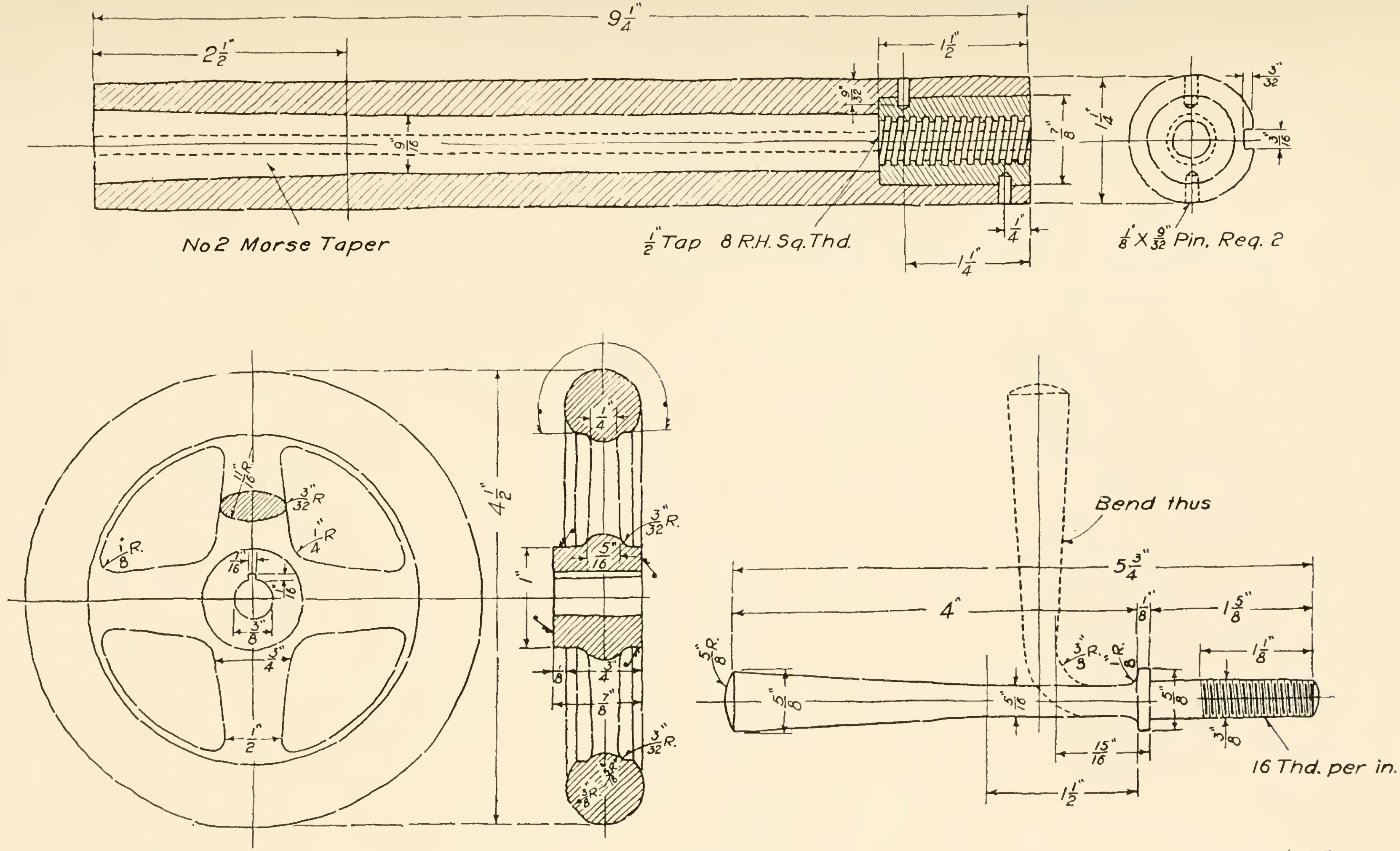


Fig. 89



No 2 Morse Taper
1/2" Tap 8 R.H. Sq. Thd.
1/8" X 9/32" Pin, Req. 2
Bend thus
16 Thd. per in.

FIG. 90

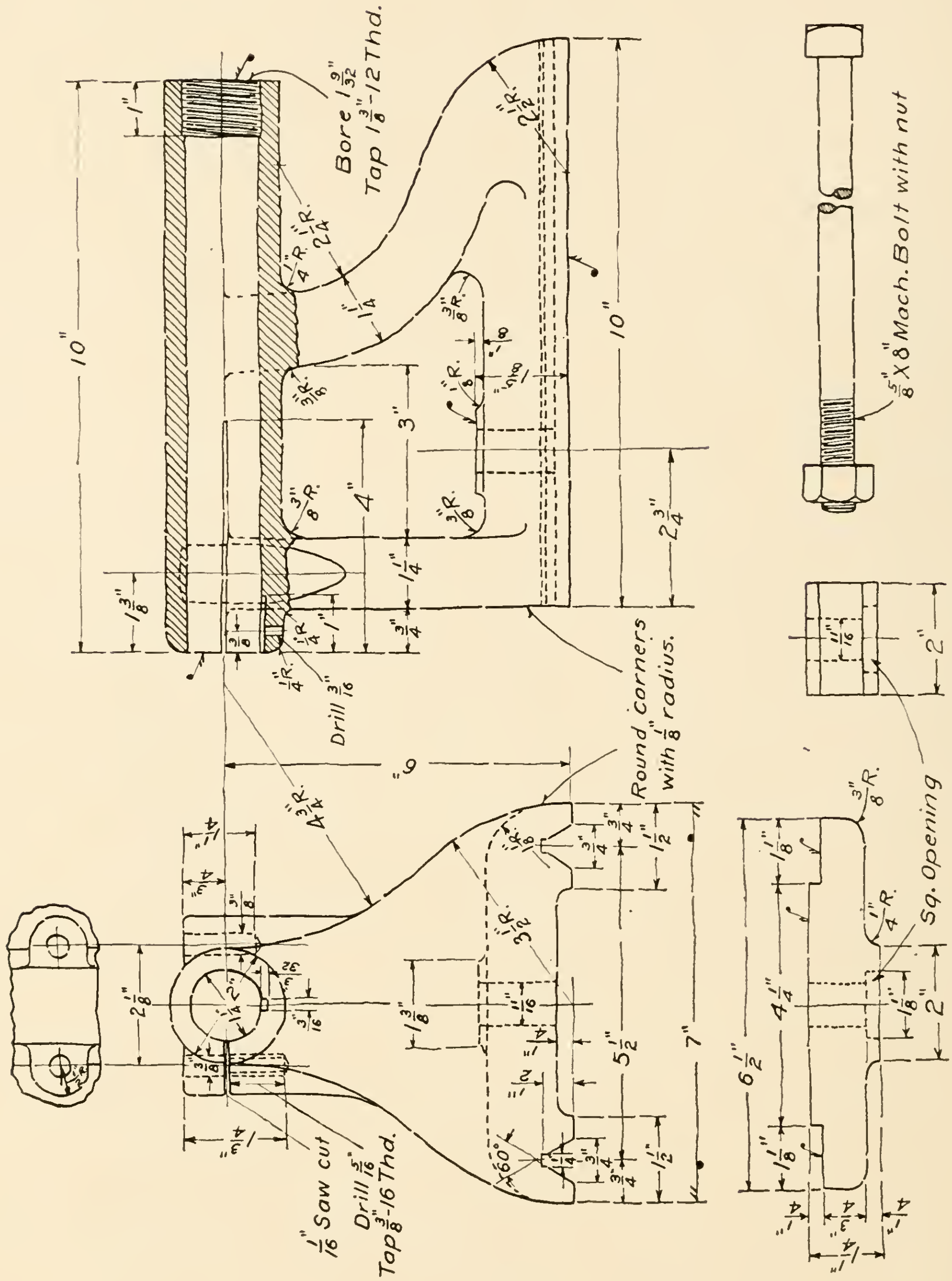

Bore 1 9/32"
Tap 1 3/8"-12 Thd.
Drill 3/16"
Round corners with 1/8" radius.
5/8" X 8" Mach. Bolt with nut
Sq. Opening
1/16" Saw cut
Drill 5/16"
Tap 3/8"-16 Thd.

FIG. 91

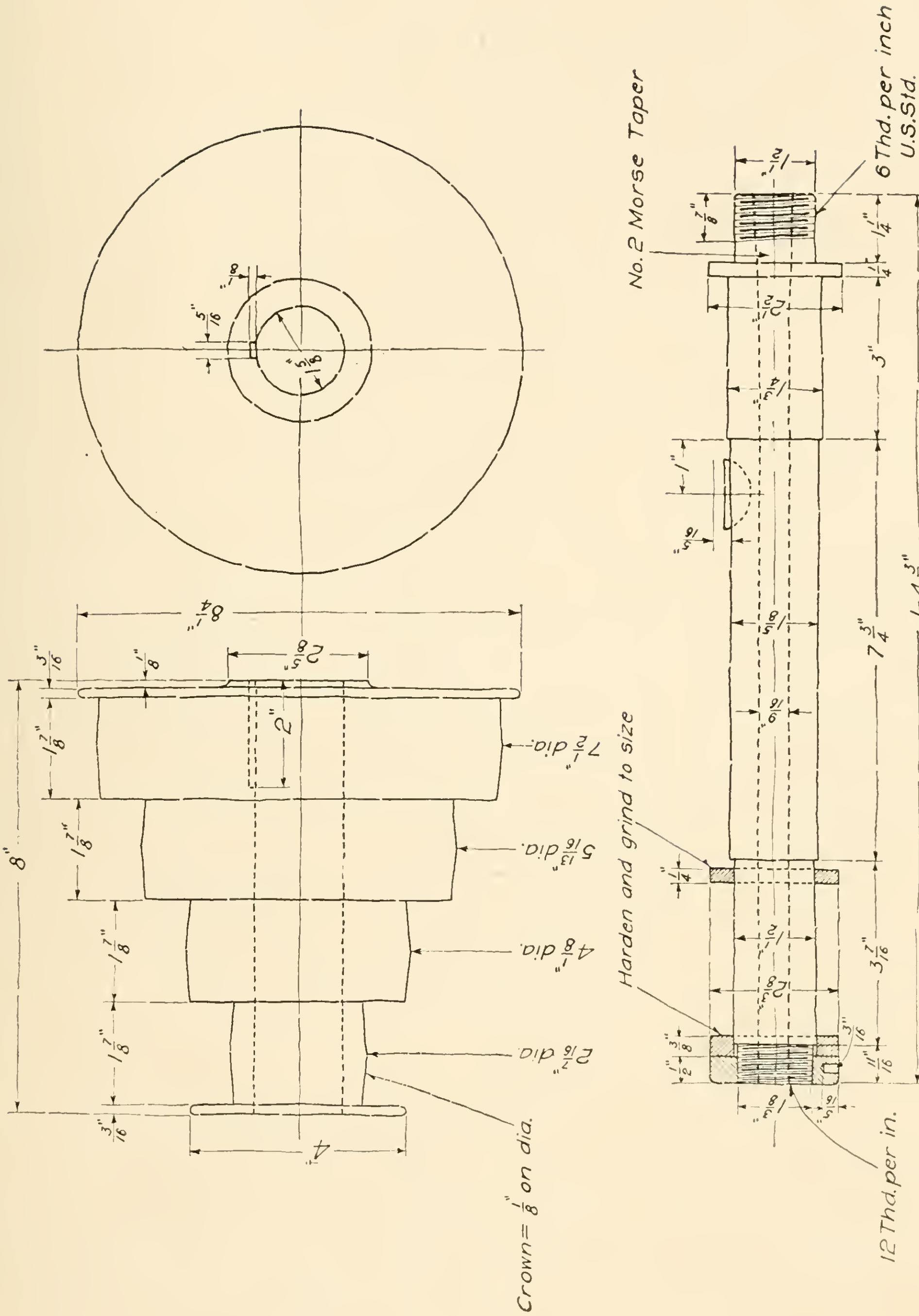

No. 2 Morse Taper
6 Thd. per inch U.S.Std.
Harden and grind to size
12 Thd. per in.
Crown = 1/8" on dia.

FIG. 92

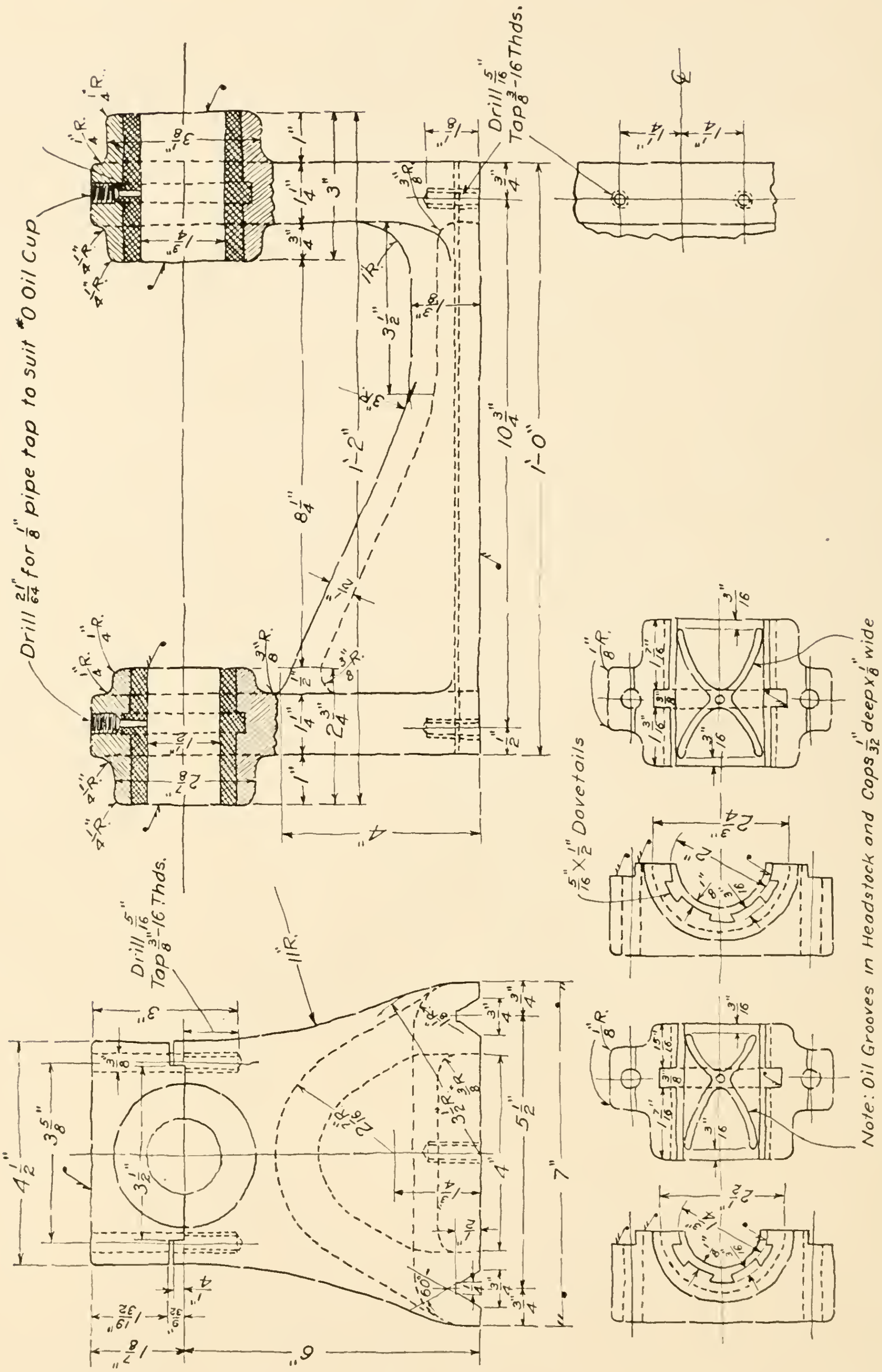

Drill 21/64" for 1/8" pipe tap to suit #0 Oil Cup
Drill 5/16" Tap 3/8"-16 Thds.
Drill 5/16" Tap 3/8"-16 Thds.
5/16" X 1/2" Dovetails
Note: Oil Grooves in Headstock and Caps 1/32" deep x 1/8" wide

FIG. 93

Make a detail drawing of the details shown in Fig. 90. Title, 12″ Speed Lathe — Tailstock Details.

From the details shown in Figs. 89, 90 and 91, make an assembly drawing. Scale, $\frac{1}{2}$ size. Title, 12″ Speed Lathe — Tailstock Assembly.

Make a detail drawing of the details shown in Fig. 92. Scale, $\frac{1}{2}$ size. Title, 12″ Speed Lathe — Headstock Details.

From the details shown in Figs. 92 and 93, make an assembly drawing. Scale, $\frac{1}{2}$ size. Title, 12″ Speed Lathe, Headstock Assembly.

From all of the speed lathe details shown from Figs. 85 to 93, inclusive, make a general assembly of this machine. This drawing should be placed on an *A* size sheet (22″ × 30″) and two views shown, the front and the headstock end, preferably. Scale, $\frac{1}{4}$ size. Title, 12″ Speed Lathe Assembly.

CHAPTER XII

TRACING AND BLUE PRINTING

Ruling Pen. — When learning to trace, one of the first difficulties encountered is the proper method of handling the ruling pen and compass.

In general, the ruling pen and the pen point of the compass should be held in such a manner as to bring the points of both jaws on the paper at the same time, as shown at (*b*) of the illustration, Fig. 94. Do not lean the pen either toward the ruling edge or away from it, but hold it in a vertical plane, for it is only when a pen is held thus, that sharp, even lines, free from a ragged edge, can be produced.

While the pen should not be leaned toward or away from the ruling edge, it will be found that the ink will flow more freely if the pen is leaned slightly *in the direction in which the line is being ruled,* as indicated at (*a*) in Fig. 94.

In Chapter No. II, mention was made of the proper method of ruling vertical lines by means of the **T** square and the *left-hand* edge of the triangle. This admonition is especially necessary when ruling these lines in ink, for it is very desirable to hold the ruling pen in an easy, natural manner, one in which the point of the pen is clearly in sight at all times.

A common mistake of most beginners is to fill the pen with too much ink, with the result that, before

they realize it, there is a big smear on their work. This is not necessarily caused by the pen being filled too full, but it is frequently the cause. It is better to fill the pen oftener and to use less ink at one time. Another excellent habit to acquire is to wipe out the pen each time fresh ink is put in, as the ink flows more freely from a clean pen than from a dirty one.

Tracing Cloth. — Tracing cloth is a fine linen fabric so prepared that it is transparent, with one

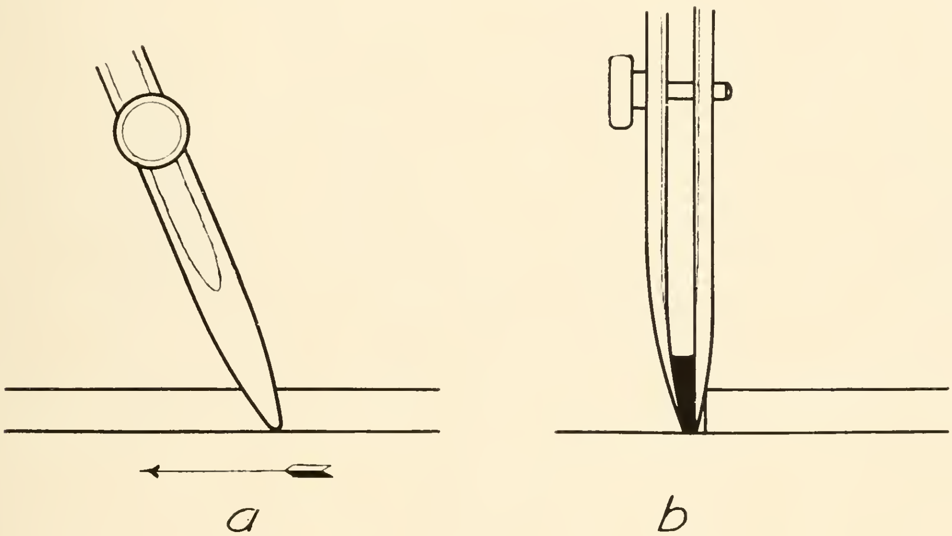


Fig. 94

side glossy and the other dull. The dull side is the one most popular with draftsmen, probably due to the fact that it takes both pencil and ink more freely than the glossy side. Ink erasures may be made more easily on the glossy side as the ink does not sink in so deeply as on the dull side, the wax-like preparation tending to carry the ink on the surface.

Owing to the sizing material with which tracing

cloth is treated, it is necessary to prepare it for use by rubbing chalk dust or talcum powder over the surface before the ink will take hold. Care should be taken to wipe off this powder after rubbing it in well, as an excess amount left on the surface tends to clog the ruling pens.

Old tracing cloth or sheets that have been spoiled, if washed out, make the best of pen wipers and rags to use in keeping the triangles and the **T** square wiped clean.

Tracing. — When beginning a tracing, tack the cloth down carefully, stretching it *tightly* over the pencil drawing, then prepare the surface with chalk as mentioned above, now adjust the compass pen to the width of outline desired; do this by trying the compass on a scrap of tracing cloth which has been prepared. In deciding on the width of line, the student should bear in mind that to get blue-prints with clear white lines, it is necessary that the lines of the tracing be fairly heavy; not the fine thin lines that beginners are so prone to use.

The illustration, Fig. 95, shows the various steps in making a tracing: First, throw in all the circles and radii; then, beginning at the top, rule in all the horizontal outlines; next, starting at the left side, rule in all the vertical outlines; and, finally, rule in the angular outlines.

Now, adjusting the pen to a much finer line, or using the small pen so adjusted, rule in the projection lines; these lines for drawings of small figures should be composed of dashes from $\frac{1}{4}$ to $\frac{3}{8}$ inch long, and for large figures from $\frac{1}{2}$ to $\frac{3}{4}$ inch long. Do *not* let the

projection lines touch the figure, but leave a slight opening between the end of the line and the figure.

Next, rule in the dimension lines; these lines for drawings of small figures should be solid except for the opening left for the dimension, but on drawings of large figures they may be broken lines of long dashes, the length to suit the size of the drawing.

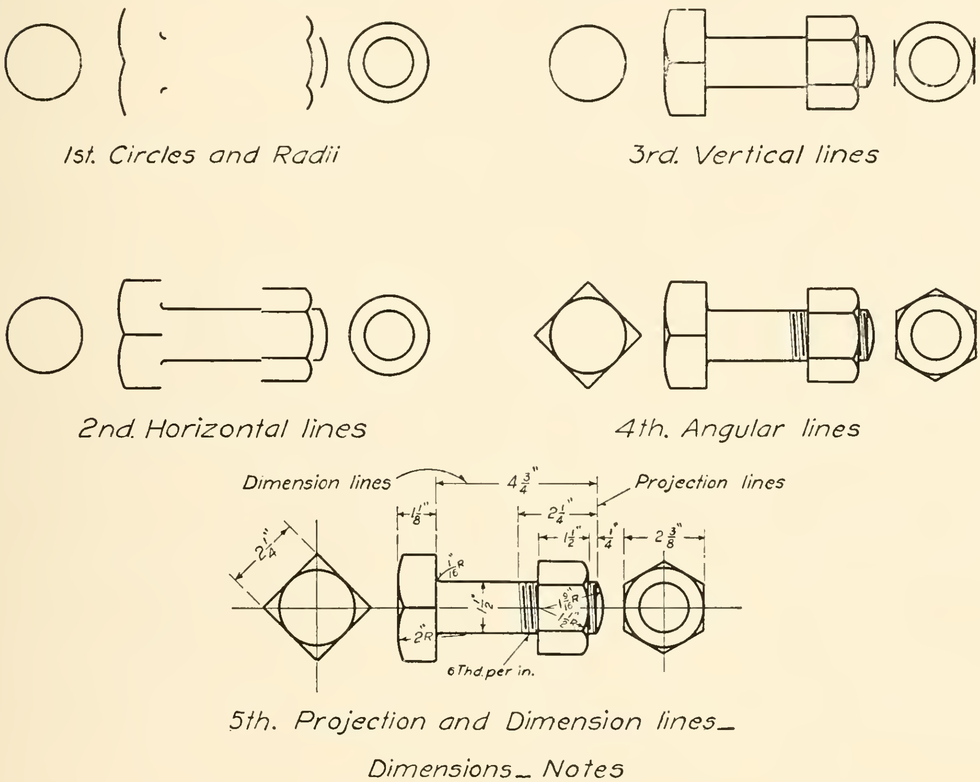


Fig. 95

Now, place the arrow-heads on the dimension lines and put in the dimensions, using care to make the figures clear and distinct; and, finally, if there is a sectional view, rule in the section lines, leaving an opening around dimensions where they occur in the sectioned part. To get the effect of contrast the section lines should be even lighter than the dimension lines.

Finished Tracing. — In the finished tracing there should be a *marked contrast* between the weight of the outlines of the figure, and of the center, projection, and dimension lines; the latter should be decidedly lighter than the outlines. When these various lines are drawn to the proper proportions and are well arranged, the figure seems to stand out by itself and is much more easily understood.

When the tracing is otherwise completed, print all notes and the title on carefully and neatly, as the appearance of a good drawing will be spoiled if the lettering is done in a careless, slipshod manner.

General Notes. — When the student attempts to letter with ink for the first time, he will discover that it is quite a different matter from lettering with a pencil. Lack of confidence and a pen point not yet properly broken in, are the major difficulties which he must overcome, and there is just one means of doing this — intelligent practice.

Guide lines on the pencil drawing that may be seen clearly through the tracing cloth, or light pencil guide lines on the tracing itself are very helpful in producing letters of uniform appearance.

Pen points of various makes are in use but one of the best for dimensioning tracings, and for all lower case lettering, is the Gillott No. 303. The De Haan double spring No. 16 is an excellent point for titles and headings where capitals are used.

Erasures on tracings require care and patience and while this is a necessary feature of the work it is a very unpopular one in drafting rooms. Where it is necessary to take out lines or smear marks,

use an ink eraser, *not* a pen-knife, as the latter in the hands of a novice will do more harm than good. An erasing shield is useful in protecting the part which is to be maintained.

After an erasure is completed, when new lines are to be inked in on this surface, this part of the tracing should be rubbed with a stick of talc (tailor's chalk) as this properly prepares the destroyed surface to take ink once more. If this is not done the ink is apt to spread and cause an ugly looking patch on the tracing.

Do not let any water drop on your tracing as the effect would be similar to that made on a starched collar.

To clean pencil marks from tracings, some of the *soft* rubbers are excellent, but to remove dirt and stains from a tracing that has been handled a good deal, use a piece of soft cotton waste soaked in benzine or gasoline as neither affects the ink and both evaporate quickly.

Blue Printing. — The tracing represents the finished record of a design which must be carefully preserved from destruction. An almost unlimited number of copies of this tracing may be made in the form of blue prints which are sent into the shops for use in the production of the mechanism illustrated by the drawing.

These blue prints are comparable to prints made from a photographic negative and are printed in very similar fashion, due allowance being made for the difference in methods of handling.

Paper. — The surface of a white paper is prepared by coating it with a chemical solution which

is affected by light; consequently this sensitized paper must be handled in a room where the light is not sufficiently bright to spoil it. When exposed to light the chemical action is such that the sensitized surface turns to a dark blue color when the print has been thoroughly washed in water.

Prepared blue print paper of various sizes and weights may be purchased in rolls and if properly protected from the light may be kept for a reasonable length of time without deterioration.

Printing. — The simplest form of blue-print frame which is used with sunlight is identical with that used for photographic printing except as to size. In large plants it is not possible, owing to the amount of work to be done, to depend upon sunlight; as a consequence, electric printing and washing machines have here replaced the old methods.

To make a blue print in a simple frame, place the tracing in the printing frame, ink side next to the glass, cover this with a sheet of prepared paper with the sensitized surface on the tracing; now clamp down tightly the padded back so as to hold the tracing and the print paper *perfectly flat;* if this is done, when the exposure is made, the light will strike all of the sensitized surface of the paper except where the ink lines intervene. After an exposure of a few minutes the print is placed in a water bath and the solution not affected by the light is thoroughly washed out. The result is a sheet with the ink lines of the tracing reproduced in white upon a dark blue background. After the print is thoroughly dry it is ready for use.

Van Dyke Prints. — Van Dyke paper prints or "Brownies," as they are frequently termed, are a convenience for certain purposes on account of their brown color and the texture of the sensitized paper which will take ink if carefully applied.

These Brownie prints are made in the same manner as blue prints, except that for certain grades of paper it is necessary to "fix" the prints in a "hypo" bath as photographic prints are treated.

As the nickname implies this print is of a dark brown color with white lines, and if we use one of these prints as a negative we obtain white prints with brownish black lines. These white prints are very convenient for sketching in changes of design, after which the print may be used as a guide when changing the original tracing.

In most drafting rooms, situations arise that necessitate preparing a special drawing on short notice, a drawing which may be used for the emergency only and then is filed away as a record. Many of these emergency drawings are for special orders which do not allow the time necessary to prepare new drawings, orders that would necessitate changing an original drawing or the production of a new one from the old, with the special features incorporated.

With the use of Van Dyke paper we may take a strong brown print from the original tracing above mentioned, but, instead of erasing the part to be changed on the original tracing, we cover with drawing ink the white lines of this part on *the Brownie,* and from this negative produce a white print. The part to be altered having been blocked out, is shown

in white, the special order change is penciled and then *inked in on this print* which, when complete, is used as an original drawing from which we may obtain blue prints to produce the special order.

CHAPTER XIII

Reference Tables

Under the head of Standard Data in the chapter on Drafting Room Conventions, mention was made of the use of reference matter as an aid to draftsmen. In choosing the various data sheets which follow we have tried to furnish only such reference matter as the student is apt to need frequently in handling the work of this text and later when taking up problems in design.

Where a definite standard has been established along the lines of the reference matter of these sheets, we have made use of it; but where no such universal standard has been developed we have used the standards of certain well known manufacturers.

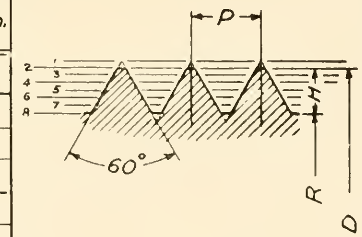
In using these reference tables the student should become familiar with the custom practiced in commercial drafting rooms in such matters, for there, there is no occasion to waste time in calculating the sizes of certain standard details of design; instead, this information is obtained from the company's standard sheets which are usually prepared by a portion of the engineering department organization.

The *form* in which this reference matter is usually presented is largely a matter of taste in conjunction

with the restrictions made by the size of the standard sheet, but the *material* itself has been carefully determined by some of the best engineering minds of the country and may be accepted as representing the mass judgment of the engineering world.

U. S. Standard Screw Threads

Bolt Diameter		Thds per In.	Dia at Root of Thread		Tap Drill, giving clearance of $\frac{1}{8}$ the height of thread triangle		Area at Root of Thread	Safe Load of Bolt. Based on fibre stress of 6000 lbs. per Sq. In.
Inches	Inches		Inches	Nearest 64th	Inches	Nearest 64th	Sq. In.	Pounds
$\frac{1}{4}$	25	20	.185	$\frac{3}{16}$	.196	$\frac{13}{64}$	.027	162
$\frac{5}{16}$	.312	18	.240	$\frac{15}{64}$	252	$\frac{1}{4}$	045	270
$\frac{3}{8}$	375	16	294	$\frac{19}{64}$	.307	$\frac{5}{16}$	.068	408
$\frac{7}{16}$	.437	14	344	$\frac{11}{32}$	360	$\frac{23}{64}$	.093	558
$\frac{1}{2}$	5	13	400	$\frac{13}{32}$	.417	$\frac{27}{64}$	126	756
$\frac{9}{16}$	.562	12	.454	$\frac{29}{64}$	.472	$\frac{15}{32}$	.162	997
$\frac{5}{8}$	625	11	507	$\frac{1}{2}$	.527	$\frac{17}{32}$	.202	1210
$\frac{3}{4}$	.75	10	.620	$\frac{5}{8}$	.642	$\frac{41}{64}$	.302	1810
$\frac{7}{8}$	.875	9	.731	$\frac{47}{64}$	.755	$\frac{3}{4}$	.420	2520
1	1.	8	.837	$\frac{27}{32}$	.865	$\frac{55}{64}$	550	3300
$1\frac{1}{8}$	1.125	7	.940	$\frac{15}{16}$	970	$\frac{31}{32}$	.694	4160
$1\frac{1}{4}$	1.25	7	1 065	$1\frac{1}{16}$	1.095	$1\frac{3}{32}$	.893	5350
$1\frac{3}{8}$	1 375	6	1.160	$1\frac{5}{32}$	1.215	$1\frac{7}{32}$	1.057	6340
$1\frac{1}{2}$	1 5	6	1 284	$1\frac{9}{32}$	1.345	$1\frac{11}{32}$	1.295	7770
$1\frac{5}{8}$	1 625	$5\frac{1}{2}$	1.389	$1\frac{25}{64}$	1.428	$1\frac{27}{64}$	1.515	9090
$1\frac{3}{4}$	1.75	5	1.491	$1\frac{31}{64}$	1.534	$1\frac{17}{32}$	1.746	10470
$1\frac{7}{8}$	1.875	5	1.616	$1\frac{39}{64}$	1.659	$1\frac{21}{32}$	2.051	12300
2	2	$4\frac{1}{2}$	1.712	$1\frac{23}{32}$	1 750	$1\frac{49}{64}$	2.302	13800
$2\frac{1}{4}$	2.25	$4\frac{1}{2}$	1.962	$1\frac{61}{64}$	2.010	$2\frac{1}{64}$	3.023	18100
$2\frac{1}{2}$	2.5	4	2.176	$2\frac{11}{64}$	2.230	$2\frac{15}{64}$	3.719	22300
$2\frac{3}{4}$	2.75	4	2.426	$2\frac{27}{64}$	2.480	$2\frac{31}{64}$	4.620	27700
3	3	$3\frac{1}{2}$	2.629	$2\frac{5}{8}$	2691	$2\frac{11}{16}$	5.428	32500



$$\text{Pitch } P = \frac{1}{\text{Nbr Thd. per Inch}}$$

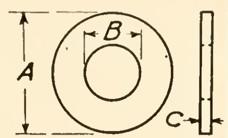
$$\text{Depth of Thd } H = P \times 6495$$

$$\text{Root dia } R = D - \frac{1.299}{\text{Nbr. Thd. per In.}}$$

$$\text{Tap Drill} = D - \frac{1.0825}{\text{Nbr. Thd. per In.}}$$

Fig. 96

WASHERS

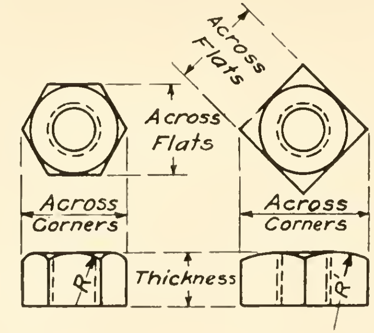


Bolt Dia.	A	B	C
$\frac{1}{4}$	$\frac{3}{4}$	$\frac{5}{16}$	*16
$\frac{5}{16}$	$\frac{7}{8}$	$\frac{3}{8}$	16
$\frac{3}{8}$	1	$\frac{7}{16}$	14
$\frac{7}{16}$	$1\frac{1}{4}$	$\frac{1}{2}$	14
$\frac{1}{2}$	$1\frac{3}{8}$	$\frac{9}{16}$	12
$\frac{9}{16}$	$1\frac{1}{2}$	$\frac{5}{8}$	12
$\frac{5}{8}$	$1\frac{3}{4}$	$\frac{11}{16}$	10
$\frac{3}{4}$	2	$\frac{13}{16}$	9
$\frac{7}{8}$	$2\frac{1}{4}$	$\frac{15}{16}$	8
1	$2\frac{1}{2}$	$1\frac{1}{16}$	8
$1\frac{1}{8}$	$2\frac{3}{4}$	$1\frac{1}{4}$	8
$1\frac{1}{4}$	3	$1\frac{3}{8}$	8
$1\frac{3}{8}$	$3\frac{1}{4}$	$1\frac{1}{2}$	7
$1\frac{1}{2}$	$3\frac{1}{2}$	$1\frac{5}{8}$	7
$1\frac{5}{8}$	$3\frac{3}{4}$	$1\frac{3}{4}$	7
$1\frac{3}{4}$	4	$1\frac{7}{8}$	7
$1\frac{7}{8}$	$4\frac{1}{4}$	2	7
2	$4\frac{1}{2}$	$2\frac{1}{8}$	7
$2\frac{1}{4}$	$4\frac{3}{4}$	$2\frac{3}{8}$	5
$2\frac{1}{2}$	5	$2\frac{5}{8}$	4

* Wire Gage

U.S. STANDARD NUTS & BOLTS

Bolt		Diameters				Thickness	
Diameter	Thds. per In.				Bottom of Thread		
.25	20	.5	.578	.707	.1850	.25	.25
.3125	18	.5938	.686	.840	.2403	.3125	.2969
.375	16	.6875	.794	.972	.2938	.375	.3438
.437	14	.7813	.902	1.105	.3447	.4375	.3906
.5	13	.875	1.011	1.237	.4001	.5	.4375
.562	12	.9688	1.119	1.370	.4542	.5625	.4844
.625	11	1.0625	1.227	1.502	.5069	.625	.5313
.75	10	1.25	1.444	1.768	.6201	.75	.625
.875	9	1.4375	1.660	2.033	7307	.875	.7188
1.	8	1.625	1.877	2.298	.8376	1.	.8125
1.125	7	1.8125	2.093	2.563	.9394	1.125	.9063
1.25	7	2.	2.310	2.828	1.0644	1.25	1.
1.375	6	2.1875	2.527	3.093	1.1585	1.375	1.0938
1.5	6	2.375	2.743	3.358	1.2835	1.5	1.1875
1.625	5.5	2.5625	2.960	3.623	1.3888	1.625	1.2813
1.75	5	2.75	3.176	3.889	1.4902	1.75	1.375
1.875	5	2.9375	3.393	4.154	1.6152	1.875	1.4688
2.	4.5	3.125	3.609	4.419	1.7113	2.	1.5625
2.25	4.5	3.5	4.043	4.949	1.9613	2.25	1.75
2.5	4	3.875	4.476	5.479	2.1752	2.5	1.9375
2.75	4	4.25	4.909	6.010	2.4252	2.75	2.125
3.	3.5	4.625	5.342	6.540	2.6288	3.	2.3125
3.25	3.5	5.	5.775	7.070	2.8788	3.25	2.5
3.5	3.25	5.375	6.208	7.600	3.1003	3.5	2.6875



Dia. Across Flats = $1\frac{1}{2}$ x Bolt dia. + $\frac{1}{8}$"

Hex. Dia. Across Corners = 1.156 x Flat dia.

Sq. Dia. Across Corners = 1.414 x Flat dia.

Thickness of Nut = Bolt dia.

Thickness of Bolt Hd. = $\frac{1}{2}$ of Flat dia.

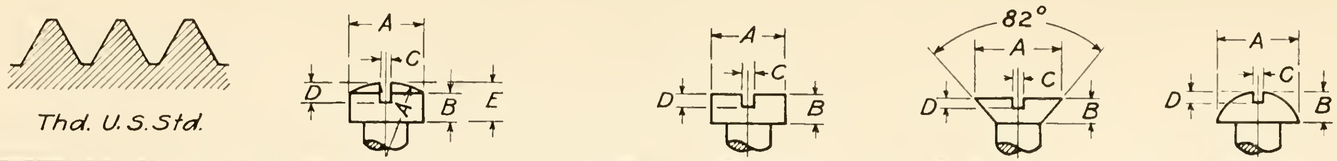
Not U. S. Std.

Radius R = Bolt dia.

Radius R' = $1\frac{1}{2}$ Bolt dia.

FIG. 97

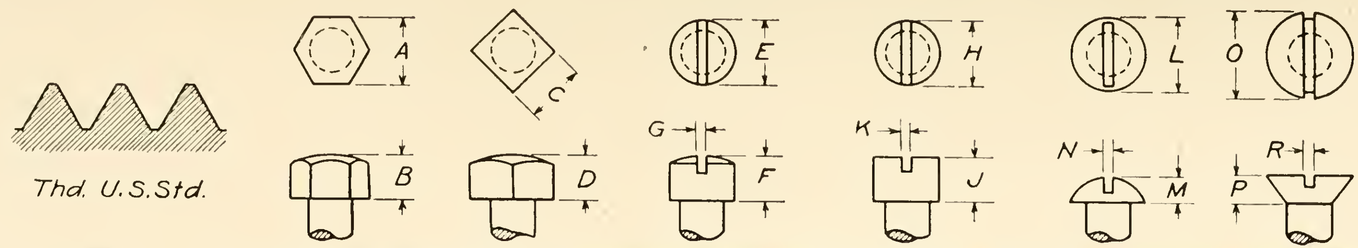
Machine Screws
A.S.M.E. Std.



Screw				Oval Fillister Head					Flat Fillister Head				Flat Head				Round Head			
No.	Dia.	Thds.	Tap Drill	A	B	C	D	E	A	B	C	D	A	B	C	D	A	B	C	D
0	.060	80	.0465	.0894	.0376	.025	.025	.0496	.0894	.0376	.025	.019	.112	.029	.025	.010	.106	.042	.025	.031
1	.073	72	.0595	.1107	.0461	.028	.030	.0609	.1107	.0461	.028	.023	.138	.037	.028	.012	.130	.051	.028	.035
2	.086	64	.070	.132	.0548	.030	.036	.0725	.132	.0548	.030	.027	.164	.045	.030	.015	.154	.060	.030	.040
3	.099	56	.0785	.153	.0633	.032	.042	.0838	.153	.0633	.032	.032	.190	.052	.032	.017	.178	.069	.032	.044
4	.112	48	.089	.1747	.0719	.034	.048	.0953	.1747	.0719	.034	.036	.216	.060	.034	.020	.202	.078	.034	.049
5	.125	44	.0995	.196	.0805	.037	.053	.1068	.196	.0805	.037	.040	.242	.067	.037	.022	.226	.087	.037	.053
6	.138	40	.110	.217	.089	.039	.059	.1180	.217	.0890	.039	.044	.262	.075	.039	.025	.250	.096	.039	.058
7	.151	36	.120	.2386	.0976	.041	.065	.1296	.2386	.0976	.041	.049	.294	.082	.041	.027	.274	.105	.041	.062
8	.164	36	.136	.2599	.1062	.043	.071	.1410	.2599	.1062	.043	.053	.320	.090	.043	.030	.298	.114	.043	.067
9	.177	32	.1405	.2813	.1148	.046	.076	.1524	.2813	.1148	.046	.057	.346	.097	.046	.032	.322	.123	.046	.071
10	.190	30	.152	.3026	.1234	.048	.082	.1639	.3026	.1234	.048	.062	.372	.105	.048	.035	.346	.133	.048	.076
12	.216	28	.173	.3452	.1405	.052	.093	.1868	.3452	.1405	.052	.070	.424	.120	.052	.040	.394	.151	.052	.085
14	.242	24	.1935	.3879	.1577	.057	.105	.2097	.3879	.1577	.057	.079	.472	.135	.057	.045	.443	.169	.057	.094
16	.268	22	.213	.4305	.1748	.061	.116	.2325	.4305	.1748	.061	.087	.528	.150	.061	.050	.491	.187	.061	.103
18	.294	20	.234	.4731	.192	.066	.128	.2554	.4731	.1920	.066	.096	.580	.164	.066	.055	.539	.205	.066	.112
20	.320	20	.261	.5158	.2092	.070	.140	.2783	.5158	.2092	.070	.104	.632	.179	.070	.060	.587	.224	.070	.122
22	.346	18	.281	.5584	.2263	.075	.150	.3011	.5584	.2263	.075	.113	.682	.194	.075	.065	.635	.242	.075	.131
24	.372	16	.295	.601	.2435	.079	.162	.3240	.601	.2435	.079	.122	.732	.209	.079	.070	.683	.260	.079	.140
26	.398	16	.323	.6437	.2606	.084	.173	.3469	.6437	.2606	.084	.130	.788	.224	.084	.075	.731	.278	.084	.149
28	.424	14	.339	.6863	.2778	.088	.185	.3698	.6863	.2778	.088	.139	.840	.239	.088	.080	.779	.296	.088	.158
30	.450	14	.368	.727	.295	.093	.201	.4024	.727	.295	.093	.147	.892	.254	.093	.085	.827	.315	.093	.167

Fig. 98

CAP SCREWS



Screw			Hexagon Head		Square Head		Oval Fils. Head			Flat Fils. Head			Button Head			Flat Head		
Dia.	Thds.	Tap Drill	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	R
$\frac{1}{4}$	20	$\frac{13}{64}$	$\frac{7}{16}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{4}$	.050	$\frac{3}{8}$	$\frac{1}{4}$	.050	$\frac{7}{16}$	.150	.050	$\frac{15}{32}$	.175	.050
$\frac{5}{16}$	18	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{5}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	.063	$\frac{7}{16}$	$\frac{5}{16}$	.063	$\frac{9}{16}$	.187	.063	$\frac{5}{8}$	.219	.063
$\frac{3}{8}$	16	$\frac{5}{16}$	$\frac{9}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{9}{16}$	$\frac{3}{8}$	.075	$\frac{9}{16}$	$\frac{3}{8}$	.075	$\frac{5}{8}$	.225	.075	$\frac{3}{4}$	.262	.075
$\frac{7}{16}$	14	$\frac{23}{64}$	$\frac{5}{8}$	$\frac{7}{16}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{7}{16}$	.088	$\frac{5}{8}$	$\frac{7}{16}$	.088	$\frac{3}{4}$	.262	.088	$\frac{13}{16}$	.306	.088
$\frac{1}{2}$	13	$\frac{27}{64}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{2}$	.100	$\frac{3}{4}$	$\frac{1}{2}$	.100	$\frac{13}{16}$	.300	.100	$\frac{7}{8}$	350	.100
$\frac{9}{16}$	12	$\frac{15}{32}$	$\frac{13}{16}$	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{9}{16}$	$\frac{13}{16}$	$\frac{9}{16}$	.113	$\frac{13}{16}$	$\frac{9}{16}$	.113	$\frac{15}{16}$	.337	.113	1	.394	.113
$\frac{5}{8}$	11	$\frac{17}{32}$	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{5}{8}$	.125	$\frac{7}{8}$	$\frac{5}{8}$	.125	1	.375	.125	$1\frac{1}{8}$	.437	.125
$\frac{3}{4}$	10	$\frac{41}{64}$	1	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{3}{4}$	1	$\frac{3}{4}$	.150	1	$\frac{3}{4}$	.150	$1\frac{1}{4}$	.450	.150	$1\frac{3}{8}$	.525	.150
$\frac{7}{8}$	9	$\frac{3}{4}$	$1\frac{1}{8}$	$\frac{7}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$	.175	$1\frac{1}{8}$	$\frac{7}{8}$	.175						
1	8	$\frac{55}{64}$	$1\frac{1}{4}$	1	$1\frac{1}{4}$	1	$1\frac{1}{4}$	1	.200	$1\frac{1}{4}$	1	.200						

Fig. 99

Decimal Equivalents

Inches

1/64	0.015625	17/64	0.265625	33/64	0.515625	49/64	0.765625
1/32	0.03125	9/32	0.28125	17/32	0.53125	25/32	0.78125
3/64	0 046875	19/64	0.296875	35/64	0.546875	51/64	0.796875
1/16	0.0625	5/16	0.3125	9/16	0.5625	13/16	0.8125
5/64	0.078125	21/64	0.328125	37/64	0.578125	53/64	0.828125
3/32	0.09375	11/32	0.34375	19/32	0.59375	27/32	0.84375
7/64	0.109375	23/64	0.359375	39/64	0.609375	55/64	0.859375
1/8	0.125	3/8	0.375	5/8	0.625	7/8	0.875
9/64	0.140625	25/64	0.390625	41/64	0.640625	57/64	0.890625
5/32	0.15625	13/32	0.40625	21/32	0.65625	29/32	0.90625
11/64	0.171875	27/64	0.421875	43/64	0.671875	59/64	0.921875
3/16	0.1875	7/16	0.4375	11/16	0.6875	15/16	0.9375
13/64	0.203125	29/64	0.453125	45/64	0.703125	61/64	0.953125
7/32	0.21875	15/32	0.46875	23/32	0.71875	31/32	0.96875
15/64	0.234375	31/64	0 484375	47/64	0.734375	63/64	0.984375
1/4	0.250	1/2	0.500	3/4	0.750	1	1.000

Fig. 100

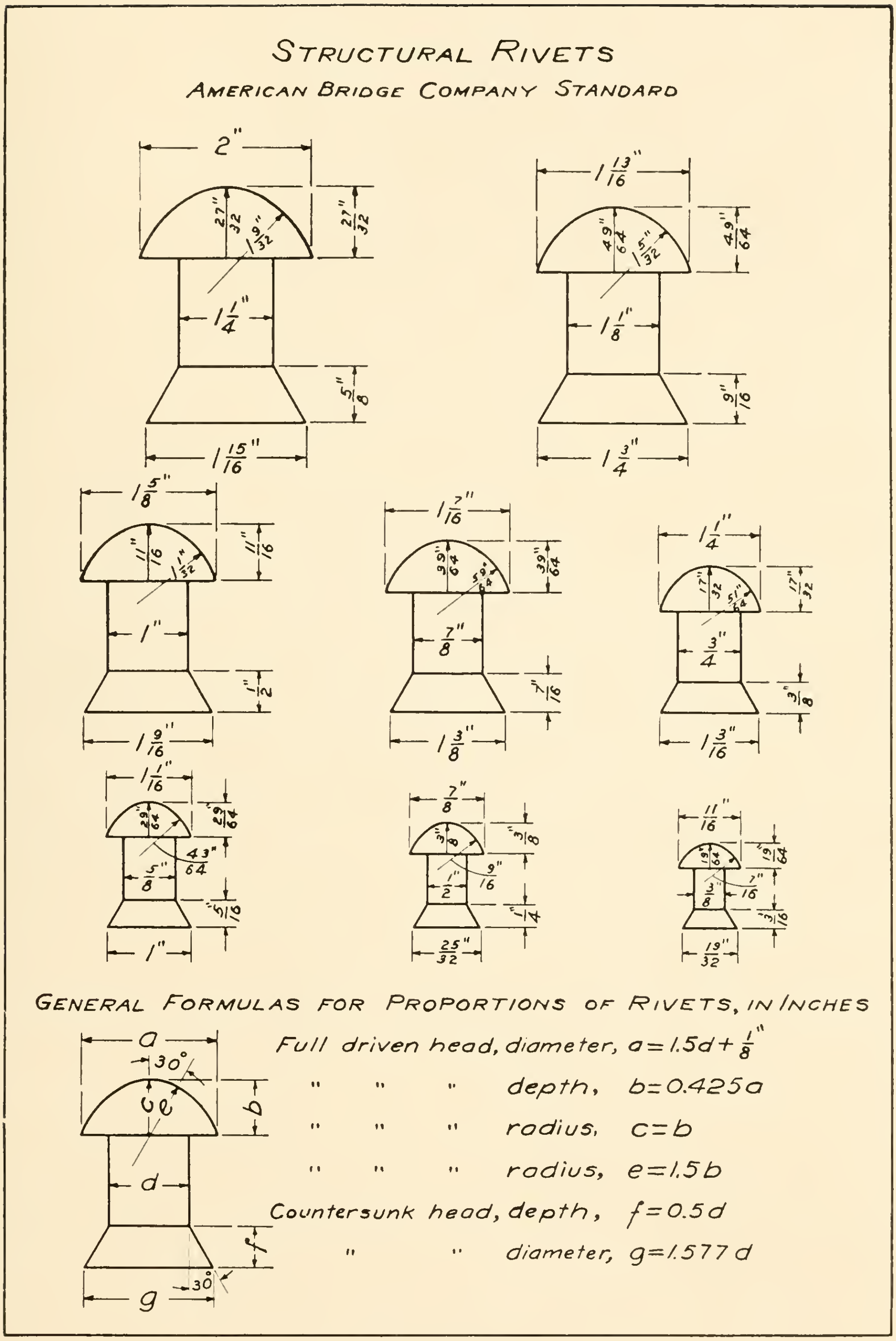
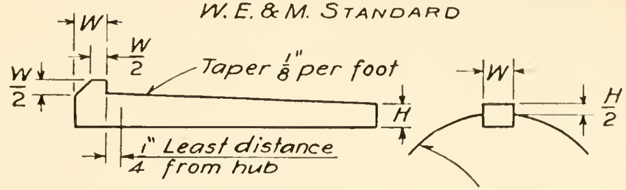

STRUCTURAL RIVETS
AMERICAN BRIDGE COMPANY STANDARD
GENERAL FORMULAS FOR PROPORTIONS OF RIVETS, IN INCHES
Full driven head, diameter, a = 1.5d + 1/8"
" " " depth, b = 0.425a
" " " radius, c = b
" " " radius, e = 1.5b
Countersunk head, depth, f = 0.5d
" " diameter, g = 1.577d

FIG. 101

TAPER KEYS

W. E. & M. STANDARD

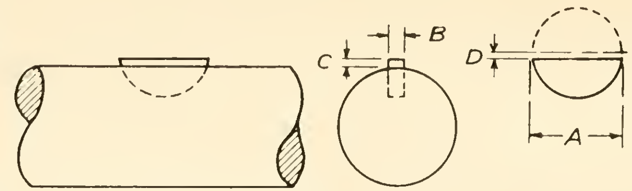


Key way taper is in hub only

Shaft & Bore Diameters	Width W	Height H	Shaft & Bore Diameters	Width W	Height H
7/16 1/2 9/16 5/8	1/8	1/8	3 15/16 4 4 1/16 4 1/8	1	11/16
11/16 3/4 13/16 7/8	3/16	3/16	4 3/16 4 1/4 4 5/16 4 3/8	1 1/16	11/16
15/16 1 1 1/16 1 1/8	1/4	3/16	4 7/16 4 1/2 4 5/8 4 3/4	1 1/8	3/4
1 3/16 1 1/4 1 5/16 1 3/8	5/16	1/4	4 7/8 5 5 1/8 5 1/4	1 1/4	7/8
1 7/16 1 1/2 1 9/16 1 5/8	3/8	1/4	5 3/8 5 1/2 5 5/8 5 3/4	1 3/8	15/16
1 11/16 1 3/4 1 13/16 1 7/8	7/16	5/16	5 7/8 6 6 1/8 6 1/4	1 1/2	1
1 15/16 2 2 1/16 2 1/8	1/2	3/8	6 3/8 6 1/2 6 5/8 6 3/4	1 5/8	1 1/16
2 3/16 2 1/4 2 5/16 2 3/8	9/16	3/8	6 7/8 7 7 1/8 7 1/4	1 3/4	1 3/16
2 7/16 2 1/2 2 9/16 2 5/8	5/8	7/16	7 3/8 7 1/2 7 5/8 7 3/4	1 7/8	1 1/4
2 11/16 2 3/4 2 13/16 2 7/8	11/16	1/2	7 7/8 8 1/2 8 3/4 9	2 1/8	1 3/8
2 15/16 3 3 1/16 3 1/8	3/4	1/2	9 1/4 9 1/2 9 3/4 10	2 1/4	1 1/2
3 3/16 3 1/4 3 5/16 3 3/8	13/16	9/16	10 1/4 10 1/2 10 3/4 11	2 3/8	1 5/8
3 7/16 3 1/2 3 9/16 3 5/8	7/8	5/8	11 1/4 11 1/2 11 3/4 12	2 1/2	1 3/4
3 11/16 3 3/4 3 13/16 3 7/8	15/16	5/8			

WOODRUFF

STANDARD KEYS

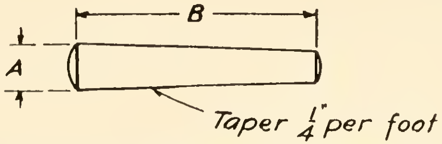


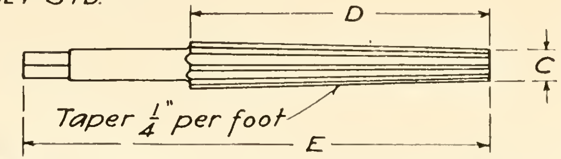
Key No	A	B	C	D	Key No	A	B	C	D
1	1/2	1/16	1/32	3/64	B	1	5/16	5/32	1/16
2	1/2	3/32	3/64	3/64	16	1 1/8	3/16	3/32	5/64
3	1/2	1/8	1/16	3/64	17	1 1/8	7/32	7/64	5/64
4	5/8	3/32	3/64	1/16	18	1 1/8	1/4	1/8	5/64
5	5/8	1/8	1/16	1/16	C	1 1/8	5/16	5/32	5/64
6	5/8	5/32	5/64	1/16	19	1 1/4	3/16	3/32	5/64
7	3/4	1/8	1/16	1/16	20	1 1/4	7/32	7/64	5/64
8	3/4	5/32	5/64	1/16	21	1 1/4	1/4	1/8	5/64
9	3/4	3/16	3/32	1/16	D	1 1/4	5/16	5/32	5/64
10	7/8	5/32	5/64	1/16	E	1 1/4	3/8	3/16	5/64
11	7/8	3/16	3/32	1/16	22	1 3/8	1/4	1/8	3/32
12	7/8	7/32	7/64	1/16	23	1 3/8	5/16	5/32	3/32
A	7/8	1/4	1/8	1/16	F	1 3/8	3/8	3/16	3/32
13	1	3/16	3/32	1/16	24	1 1/2	1/4	1/8	7/64
14	1	7/32	7/64	1/16	25	1 1/2	5/16	5/32	7/64
15	1	1/4	1/8	1/16	G	1 1/2	3/8	3/16	7/64

FIG. 102

TAPER PINS & REAMERS

PRATT & WHITNEY STD.





Size: Diameter A, Approx.	Diameter A, Inches	No.	5/8	3/4	7/8	1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5	5 1/4	5 1/2	5 3/4	6	Reamers: No.	Dia. C	Length D	Length E
5/32	.156	0		●		●																					0	.135	1 1/2	2 1/4
11/64	.172	1		●		●	●																				1	.146	1 3/4	2 1/2
3/16	.193	2		●		●	●	●																			2	.162	2	3
7/32	.219	3		●		●	●	●	●																		3	183	2 1/4	3 1/2
1/4	.250	4		●		●	●	●	●	●																	4	208	2 1/2	4
19/64	.289	5		●		●	●	●	●	●	●																5	.240	3	4 1/2
11/32	.341	6		●		●	●	●	●	●	●	●	●	●	●												6	.279	3 5/8	5
13/32	.409	7				●	●	●	●	●	●	●	●	●	●	●	●										7	331	4 1/2	6
1/2	.492	8					●	●	●	●	●	●	●	●	●	●	●	●	●	●							8	.398	5 1/4	6 3/4
19/32	.591	9						●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●				9	.482	6 1/8	8
23/32	.706	10						●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	10	.581	7	9

● Stock sizes

Each reamer overlaps the next smaller size

FIG. 103

Standard Pipe
National Tube Company Standard

Size In.	Diameters, Inches		Thickness, Inches	Weight per foot, Pounds		Thds. per In.	Couplings		
	External	Internal		Plain Ends	Thds. Couplings		Dia. In.	Lgth. In.	Weight Pounds
1/8	.405	.269	.068	.244	.245	27	.562	7/8	.029
1/4	.540	.364	.088	.424	.425	18	.685	1	.043
3/8	.675	.493	.091	.567	.568	18	.848	1 1/8	.070
1/2	.840	.622	.109	.850	.852	14	1.024	1 3/8	.116
3/4	1.050	.824	.113	1.130	1.134	14	1.281	1 5/8	.209
1	1.315	1.049	.133	1.678	1.684	11 1/2	1.576	1 7/8	.343
1 1/4	1.660	1.380	.140	2.272	2.281	11 1/2	1.950	2 1/8	.535
1 1/2	1.900	1.610	.145	2.717	2.731	11 1/2	2.218	2 3/8	.743
2	2.375	2.067	.154	3.652	3.678	11 1/2	2.760	2 5/8	1.208
2 1/2	2.875	2.469	.203	5.793	5.819	8	3.276	2 7/8	1.720
3	3.500	3.068	.216	7.575	7.616	8	3.948	3 1/8	2.498
3 1/2	4.000	3.548	.226	9.109	9.202	8	4.591	3 5/8	4.241
4	4.500	4.026	.237	10.790	10.889	8	5.091	3 5/8	4.741
4 1/2	5.000	4.506	.247	12.538	12.642	8	5.591	3 5/8	5.241
5	5.563	5.047	.258	14.617	14.810	8	6.296	4 1/8	8.091
6	6.625	6.065	.280	18.974	19.185	8	7.358	4 1/8	9.554
7	7.625	7.023	.301	23.544	23.769	8	8.358	4 1/8	10.932
8	8.625	8.071	.277	24.696	25.000	8	9.358	4 5/8	13.905
8	8.625	7.981	.322	28.554	28.809	8	9.358	4 5/8	13.905
9	9.625	8.941	.342	33.907	34.188	8	10.358	5 1/8	17.236
10	10.750	10.192	.279	31.201	32.000	8	11.721	6 1/8	29.877
10	10.750	10.136	.307	34.240	35.000	8	11.721	6 1/8	29.877
10	10.750	10.020	.365	40.483	41.132	8	11.721	6 1/8	29.877
11	11.750	11.000	.375	45.557	46.247	8	12.721	6 1/8	32.550
12	12.750	12.090	.330	43.773	45.000	8	13.958	6 1/8	43.098
12	12.750	12.000	.375	49.562	50.706	8	13.958	6 1/8	43.098
13	14.000	13.250	.375	54.568	55.824	8	15.208	6 1/8	47.152
14	15.000	14.250	.375	58.573	60.375	8	16.446	6 1/8	59.493
15	16.000	15.250	.375	62.579	64.500	8	17.446	6 1/8	63.294

The permissible variation in weight is 5 per cent above and 5 per cent below. Furnished with threads and couplings and in random lengths unless otherwise ordered. Taper of threads is $\frac{3}{4}''$ diameter per foot length for all sizes. The weight per foot of pipe with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet.

All weights and dimensions are nominal. On sizes made in more than one weight, weight desired must be specified.

Fig. 104

STANDARD GAGES

Gage No.	Birmingham Wire. (B.W.G.) Stubs Iron Wire	American Wire or B.&S.	American Steel & Wire Co. formerly W.&M.	Trenton Iron Co.	British Imperial Standard Wire (S.W.G.)	Standard Birmingham Sheet & Hoop (B.G.)	Gage No	Birmingham Wire. (B.W.G.) Stubs Iron Wire	American Wire or B.&S.	American Steel & Wire Co. formerly W.&M.	Trenton Iron Co.	British Imperial Standard Wire (S.W.G.)	Standard Birmingham Sheet & Hoop (B.G.)
0000000			.4900		.500		18	.049	.040303	.0475	.045	.048	.0495
000000		.580000	.4615		.464		19	.042	.035890	.0410	.040	.040	.0440
00000	.500	.516500	.4305	.450	.432		20	.035	.031961	.0348	.035	.036	.0392
0000	.454	.460000	.3938	.400	.400		21	.032	.028462	.03175	.031	.032	.0349
000	.425	.409642	.3625	.360	.372	.5000	22	.028	.025346	.0286	.028	.028	.03125
00	.380	.364796	.3310	.330	.348	.4452	23	.025	.022572	.0258	.025	.024	.02782
0	.340	.324861	.3065	.305	.324	.3964	24	.022	.020101	.0230	.0225	.022	.02476
1	.300	.289297	.2830	.285	.300	.3532	25	.020	.017900	.0204	.020	.020	.02204
2	.284	.257627	.2625	.265	.276	.3147	26	.018	.015941	.0181	.018	.018	.01961
3	.259	.229423	.2437	.245	.252	.2804	27	.016	.014195	.0173	.017	.0164	.01745
4	.238	.204307	.2253	.225	.232	.2500	28	.014	.012641	.0162	.016	.0148	.015625
5	.220	.181940	.2070	.205	.212	.2225	29	.013	.011257	.0150	.015	.0136	.0139
6	.203	.162023	.1920	.190	.192	.1981	30	.012	.010025	.0140	.014	.0124	.0123
7	.180	.144285	.1770	.175	.176	.1764	31	.010	.008928	.0132	.013	.0116	.0110
8	.165	.128490	.1620	.160	.160	.1570	32	.009	.007950	.0128	.012	.0108	.0098
9	.148	.114423	.1483	.145	.144	.1398	33	.008	.007080	.0118	.011	.0100	.0087
10	.134	.101897	.1350	.130	.128	.1250	34	.007	.006305	.0104	.010	.0092	.0077
11	.120	.090742	.1205	.1175	.116	.1113	35	.005	.005615	.0095	.0095	.0084	.0069
12	.109	.080808	.1055	.105	.104	.0991	36	.004	.005000	.0090	.009	.0076	.0061
13	.095	.071962	.0915	.0925	.092	.0882	37		.004453	.0085	.0085	.0068	.0054
14	.083	.064084	.0800	.0806	.080	.0785	38		.003965	.0080	.008	.0060	.0048
15	.072	.057068	.0720	.070	.072	.0699	39		.003531	.0075	.0075	.0052	
16	.065	.050821	.0625	.061	.064	.0625	40		.003144	.0070	.007	.0048	
17	.058	.045257	.0540	.0525	.056	.0556							

FIG. 105